THE DISEASES OF THE TEA BUSH

MACMILLAN AND CO., LIMITED
LONDON • BOMBAY • CALCUTTA • MADRAS
MELBOURNE

THE MACMILLAN COMPANY
NEW YORK • BOSTON • CHICAGO
DALLAS • SAN FRANCISCO

THE MACMILLAN CO. OF CANADA, LTD.
TORONTO

THE DISEASES OF THE TEA BUSH

BY

T. PETCH, B.A., B.Sc.

BOTANIST AND MYCOLOGIST TO THE GOVERNMENT OF CEYLON

MACMILLAN AND CO., LIMITED
ST. MARTIN'S STREET, LONDON

1923

PRINTED IN GREAT BRITAIN

PREFACE

The cultivation of tea within the British Empire was begun about the year 1836, and there are now more than a million acres in India and Ceylon under that product. Originating, as it did, at a time when the application of science to agriculture was almost unknown, and when many of our modern agricultural sciences had not been conceived, it has survived the ills and errors of an unguided youth, and has attained a mature age, without ever having been compelled to enquire seriously into the foundations of its existence and the perils of a future state, except in so far as its prospects were temporarily obscured by over-production. Consequently, the literature relating to the cultivation of tea is not exhaustive, and, *a fortiori*, that on the diseases of the tea bush is still more incomplete.

As a matter of fact, the tea bush is a very hardy plant, and it has not hitherto suffered exceptionally from any disease. At the outset, bushes were doubtless killed in large numbers, as sometimes happens at the present day, by the root diseases which are often prevalent in new clearings; but, in that era, "poisonous roots," "slab rock," "wet feet," and "environmental conditions" were considered a sufficient explanation of their demise,—labour-saving views to which some, mistaking the particular for the general, would have us return.

Watt and Mann, in their summary of the diseases of the tea bush published in 1903, were able to describe only a dozen diseases, though they stated that diseases appeared to be growing in number and in virulence every season.

In the present work, some sixty diseases are enumerated,—a large increase, but not an alarming one when it is remembered that the investigation of the diseases of tea on the spot has been almost entirely subsequent to the publication of Watt and Mann's book, and that part of the apparent increase is due to the closer investigation of the old diseases and the consequent recognition of different diseases which were formerly grouped together under one name.

The conditions under which tea is usually grown do not unduly favour disease. As it is kept pruned down, the bushes are not subject to a permanently high humidity, while the periodic pruning, though it may, on occasion, induce consequences which are undesirable from the point of view of plant pathology, affords an opportunity of getting rid of various diseases. The systematic manuring which is now generally practised also assists in keeping disease in check.

Nevertheless, opinions are not lacking that, as the tea bush grows older, diseases are becoming more prevalent; and at the suggestion of several correspondents, the present work has been written, in order that the planter may recognise the diseases which have been recorded, and may take steps to control them when they appear or to lessen the probability of their occurrence.

A preliminary chapter on fungi in general has been included, by request, in order to furnish explanations of the technical terms employed in the descriptions of diseases. It is to be regarded as a running glossary, not as a complete account of the classification of fungi. The arrangement adopted is merely that which promised to be most intelligible to the layman, and is not intended to express any views on the evolution of fungi.

CONTENTS

CHAPTER I

PAGE

The Classification of Fungi 1

CHAPTER II

Leaf Diseases 22

Grey Blight. Brown Blight. Copper Blight. Bird's-eye Spot. *Cercosporella Theae.* Rim Blight. Japanese *Exobasidium* Blight. Sooty Mould. *Phoma theicola. Phaeosphaerella Theae.* Scabbed leaves. Leaf disease in nurseries. *Hendersonia theicola. Gloeosporium Theae-sinensis. Septoria Theae. Discosia Theae. Phyllosticta Theae. Macrophoma Theae. Macrosporium commune* Rabh. var. *theicolum* Spesch., and *Pleospora Theae. Venturia Speschnewii. Chaetophoma Penzigi.* Chlorosis. Double leaves. Dwarf leaves.

CHAPTER III

Leaf and Stem Diseases 51

Blister Blight. Red Rust. Bacterial leaf and stem disease. Black Rot. Indian parasitic Thread Blight. Epiphytic Thread Blight. White Stem Blight. Horse-hair Blight.

CHAPTER IV

Stem Diseases 87

Branch Canker (*Nectria* sp.). Branch Canker (*Macrophoma theicola*). Pink disease. Die-back (*Nectria cinnabarina*). Die-back (*Stilbella Theae*). Die-back of plucked shoots. Thorny Stem Blight. *Massaria theicola.* Stump Rot (*Irpex destruens*). Velvet Blight and *Septobasidium* spp. The Grey fungus of the dadap. Ringing of

PAGE

new shoots from collar-pruned bushes. Collar rot of nursery plants. Lichens and mosses. Fasciation. Galls on plucked shoots. Burrs. Abnormal callus outgrowths.

CHAPTER V

Root Diseases 127

Rosellinia arcuata. *Rosellinia bunodes*. *Rosellinia* sp. *Ustulina zonata*. *Sphaerostilbe repens*. *Diplodia*. Red Root disease. *Poria hypobrunnea*. *Trametes Theae*. Brown Root disease. *Fomes lignosus*. *Fomes lucidus*. *Fomes applanatus*. *Polyporus mesotalpae*. *Polyporus interruptus*. *Irpex subvinosus*. Root-splitting disease. Root diseases of nursery plants. "Bitten off" root disease. *Sclerotium* disease. Treatment of nursery root diseases.

CHAPTER VI

Wound Covers, Sprays, and Sprayers 180

Pruning cuts. Gondal fluid. Spraying machines. Bordeaux mixture. Woburn Bordeaux. Burgundy mixture. An adhesive mixture. Lime-sulphur solution. Alkaline washes. Copper-soda emulsion (Woburn winter wash).

CHAPTER VII

Mycological Notes 191

CHAPTER VIII

Fungi on the Tea Bush 203

Bibliography 213

Index 217

ILLUSTRATIONS

IN COLOUR

PLATE FACING PAGE

I. Leaf Diseases 32

Fig. 1, Grey Blight; Fig. 2, Brown Blight; Fig. 3, *Cercosporella Theae*, early stage; Fig. 4, *Cercosporella Theae*, fully developed spots; Fig. 5, *Cercosporella Theae*, irregular patches on full-grown leaf; Fig. 6, *Phoma theicola*; Fig. 7, Scabbed leaf, early stage; Fig. 8, Scabbed leaf, fully developed stage; Fig. 9, early stage of attack of Black Rot on young leaf; Fig. 10, Bird's-eye Spot. Fig. 10, natural size; the remainder, $\times \frac{2}{3}$.

II. Stem and Root Diseases 112

Fig. 1, Red Rust on tea leaf, $\times \frac{2}{3}$; Fig. 2, Red Rust on leaf, a superficial alga patch, $\times 12$; Fig. 3, Red Rust, parasitic form, on tea leaf; Fig. 4, Red Rust on a tea stem; Fig. 5, Red Rust on tea stem, $\times 12$, showing the sporangiophores; Fig. 6, *Corticium salmonicolor*, fructification on a tea stem; Fig. 7, *Irpex destruens*, fructification, upper surface; Fig. 8, *Septobasidium* sp. (parasitic), young advancing edge; Fig. 9, *Septobasidium* sp. (parasitic), older part; Fig. 10, *Poria hypolateritia*, fructification; Fig. 11, *Poria hypolateritia*, mycelium on root. All natural size, unless otherwise stated.

III. Root Diseases 160

Fig. 1, *Fomes lignosus*, upper surface, $\times \frac{1}{2}$; Fig. 2, *Fomes lignosus*, lower surface; Fig. 3, *Fomes lignosus*, section of fructification; Fig. 4, mycelium of *Fomes lignosus*; Fig. 5, *Poria hypobrunnea*, a fully developed fructification; Fig. 6, *Poria hypobrunnea*, section of fructification, $\times 3$; Fig. 7, root attacked by Brown Root disease, showing brown lines internally; Fig. 8, wood attacked by Brown Root disease, showing brown bands; Fig. 9, *Fomes lamaoensis*, section of fructification; Fig. 10, *Fomes lamaoensis*, upper surface, $\times \frac{1}{2}$. All natural size, unless otherwise stated.

TEXT FIGURES

FIG. PAGE

1. Hyphae. 1, *Penicillium* spore (shaded) producing a mycelium, $\times$ 500; 2, hypha of *Rosellinia arcuata*, $\times$ 500; 3, hypha of *Polyporus molliculus*, with clamp connection, $\times 500$ 2

2. *Sclerotium* (*Mylitta*) *ligulatum*, $\times \frac{2}{3}$; found on up-country tea estates in Ceylon 3

FIG. PAGE

3. Forms of spores.—1, *Fusarium*, ×600; 2, *Colletotrichum Camelliae*, ×500, the lower spore germinating; 3, *Fomes lucidus*, ×800; 4, *Botryodiplodia Theobromae*, ×400; 5, *Macrophoma theicola*, ×500; 6, *Pestalozzia palmarum*, ×800; 7, *Macrosporium commune*, ×500; 8, *Cercospora Theae*, ×300 4
4. Conidiophores and conidia. 1, *Helminthosporium Heveae*, ×300; 2, *Oidium*, ×250; 3, *Penicillium*, ×250; *Aspergillus*, ×250 . . 5
5. 1, *Stilbum nanum*, ×50; 2, Conidiophores and conidia of *Stilbum nanum* (diagrammatic), ×350; 3, *Didymostilbe Coffeae*, ×50; 4, conidia of same, ×600; 5, head of same, ×500 6
6. *Colletotrichum Camelliae*, section through an acervulus, showing setae and conidia, ×350 7
7. *Macrophoma theicola*, section through a pycnidium, showing the spores. ×450 9
8. 1, *Nectria haematococca*, ×150; 2, section of the same, showing asci and ascospores, ×150 10
9. 1, *Peziza sulcipes*, natural size; 2, *Peziza sarmentorum*, natural size; 3, ascus and paraphyses of *Peziza sarmentorum*, ×300 . . . 12
10. 1, Sporangia of *Phytophthora Faberi*, ×400; 2, a resting conidium of the same, ×400; 3, Oogonium (upper) and antheridium (lower) of *Phytophthora Meadii*, ×400; 4, escaping zoospores of *Phytophthora Meadii*, ×400 13
11. 1, *Oudemansiella apalosarca*, small specimen, natural size; 2, longitudinal section of same, showing the gills, natural size; 3, basidia and a cystidium of the same, ×250; 4, *Marasmius equicrinis*, ×1½; 5, the under side of the pileus of *Marasmius equicrinis*, showing the gills, ×1½ . . 16
12. *Hexagonia apiaria*. ×⅔ 18
13. The effect of Brown Blight. ×½ 32
14. *Cercosporella Theae*; spots on young leaf. Natural size . . . 37
15. Conidiophore and conidia of *Cercosporella Theae*. ×300 . . . 37
16. Effect of *Phaeosphaerella Theae*. Natural size 43
17. Shoots bearing dwarf leaves, arising from a branch with normal leaves. Natural size 50
18. Blister Blight on a tea leaf. Natural size 52
19. Sporangiophore of *Cephaleuros*, ×300; and a zoospore, ×500 . . 58
20. A tea bush attacked by Red Rust 60
21. The effect of Black Rot on Coca; lower leaves decayed, upper leaves healthy. ×⅙ 67
22. *Corticium Theae*, section of the film on a tea leaf, showing the basidia and spores. ×600. (After Bernard) 71
23. *Corticium* sp. in fructification on stem of Coca. ×½ 72
24. Parasitic Thread Blight on *Gymnosporia*. Natural size . . . 75
25. Anker cells from the Indian parasitic Thread Blight. ×800 . . 76
26. Epiphytic Thread Blight (*Marasmius pulcher*) on tea leaf and stem, with a dead leaf attached. ×½ 79
27. Epiphytic Thread Blight on tea stem. ×¼ 80
28. *Marasmius pulcher*, "*Cyphella*" form. ×8 80
29. White Stem Blight on tea. ×½ 81

FIG. PAGE

30. The effect of White Stem Blight on a tea leaf, $\times \frac{2}{3}$; the paler area is yellow and papery 82
31. Horse-hair Blight on nutmeg. $\times \frac{1}{2}$ 84
32. Old Branch Canker, viewed from above, $\times \frac{1}{6}$; the wounds extend upwards inside the branches and are seen as holes in the cut ends . . . 89
33. Branch Canker on young stems after an attack of Pink Disease. Natural size 91
34. *Macrophoma theicola*, pycnidia exposed by shaving a diseased stem. $\times 10$ 96
35. Branch Canker caused by *Macrophoma theicola* on the red wood. $\times \frac{2}{5}$. 97
36. Branch Canker caused by an attack of *Macrophoma theicola* at the base of a stem. $\times \frac{1}{2}$ 98
37. An early stage of Branch Canker on a horizontal branch. $\times \frac{1}{3}$ . . 99
38. Die-back of plucked shoots. $\times \frac{1}{2}$ 105
39. Thorny Stem Blight. $\times \frac{3}{4}$ 107
40. Longitudinal section of stem attacked by *Massaria theicola*. $\times \frac{1}{4}$ . . 109
41. *Irpex destruens* on a tea stump. $\times \frac{1}{3}$ 112
42. *Septobasidium* on a tea bush. $\times \frac{1}{2}$ 115
43. Collar rot of nursery plants, natural size : 1, early stage ; 2, advanced stage 119
44. A fasciated tea stem. $\times \frac{1}{2}$ 124
45. Gall on a plucked shoot. Natural size 124
46. Burr on a tea stem. $\times \frac{1}{4}$ 125
47. Abnormal callus outgrowths. $\times \frac{1}{2}$ 126
48. *Rosellinia arcuata*. 1, Mycelium on the exterior of a root, natural size ; 2, stars of mycelium between the wood and the bark, natural size ; 3, conidiophores, $\times 4$; 4, a group of perithecia, $\times 4$; 5, ascospores, $\times 500$ 134
49. Injury caused by *Rosellinia* on the main stem of a tea bush. $\times \frac{1}{2}$ . . 137
50. *Rosellinia bunodes*. 1, Mycelium on the wood of the root, natural size ; 2, black lines in the root, longitudinal section, natural size ; 3, cross-section of a root showing the black ring, natural size ; 4, a cluster of perithecia, $\times 6$; 5, ascospores, $\times 400$ 140
51. Tea bush attacked by *Ustulina zonata*, showing fans of mycelium between the bark and the wood. $\times \frac{1}{2}$ 142
52. *Ustulina zonata* ; fructification developing on the stem of a tea bush. $\times \frac{3}{4}$ 143
53. *Ustulina zonata*. Lower figure, the fructification, natural size ; upper figure, cross-section of the fructification, showing the perithecial cavities. $\times 6$ 144
54. *Sphaerostilbe repens* ; mycelium on the wood of a *Hevea* root . . 147
55. *Sphaerostilbe repens* ; details of the fungus 148
56. Tea root attacked by *Botryodiplodia Theobromae*, showing black heaps of spores surrounded by a white fringe. $\times \frac{1}{2}$ 150
57. *Poria hypolateritia* ; fructification on the stem of a tea bush. $\times \frac{1}{3}$. 157
58. Brown Root disease ; mycelium and adhering soil, etc., on the tap root of a young tea bush. $\times \frac{1}{2}$ 160
59. *Fomes lignosus*, mycelium on root. $\times \frac{1}{2}$ 163
60. *Fomes lucidus* ; fructifications on the stem of *Limonia*. $\times \frac{1}{8}$ . . 166
61. *Fomes applanatus* ; fructification on a tea stem. $\times \frac{1}{6}$ . . . 168
62. *Fomes applanatus* ; fructification in the middle of a tea bush. $\times \frac{1}{6}$. 168

FIG. PAGE

63. *Polyporus mesotalpae*; fructification on a tea bush. $\times \frac{1}{6}$ . . . 170
64. Mycelium of *Polyporus interruptus* on the root of a tea bush. $\times \frac{1}{3}$ . . 172
65. *Polyporus interruptus.* 1, *Poria* form of fructification, natural size; 2 and 3, *Polyporus* form on a lateral root of tea, viewed from above, natural size 173
66. Fructification of *Irpex subvinosus.* Natural size 174
67. Fructifications of *Armillaria fuscipes* on a stump of *Acacia decurrens.* $\times \frac{1}{6}$ 176
68. Root disease of germinating seeds. Natural size. (After Bernard) . 178
69. "Bitten off" root disease. Natural size 178

CHAPTER I

THE CLASSIFICATION OF FUNGI

FUNGI are plants which differ from flowering plants, ferns, mosses, and algae, in that they do not possess the green colouring matter known as chlorophyll. In consequence, they are unable to build up their food from the carbon dioxide of the air, and must obtain it from other plants or from animals. Some fungi grow on, or in, and obtain their food from, living plants; these are known as *parasitic* fungi. Others grow and feed on dead plants, fallen timber, or other vegetable debris, and are known as *saprophytic* fungi. This division is not a rigid one. Some fungi are always parasitic, others are always saprophytic. But there are very many fungi which, though, as a rule, saprophytic, can under certain circumstances become parasitic; these are classed as *facultative parasites*. Many of the fungi which cause disease on tropical plantations belong to this last-named class; after beginning life saprophytically on dead stumps or fallen timber, they attack the cultivated plants. The plant on which a fungus grows is said to be its *host*,—a somewhat illogical extension of the customary meaning of that term.

As in the flowering plants, a fungus consists of a vegetative part (*i.e.* a part devoted to the acquisition of food) and a reproductive part. The vegetative part consists of very fine filaments or threads which are known as hyphae. A *hypha* (Greek, *hyphe*, a web) is a hollow cylindrical tube, containing protoplasm, and divided at intervals by cross partitions, *septa* (Latin, *septum*, a wall). The average diameter of a fungus hypha is about one five-thousandth

part of an inch.[1] A hypha one two-thousandth part of an inch in diameter would be very large, while one one-thousandth part of an inch in diameter would be prodigious. It will be evident, therefore, that, in general, single hyphae are invisible to the naked eye. It is only when they are aggregated into sheets or strands that they become visible without a microscope. A collection of hyphae belonging to one individual fungus, whether running separately or united into strands, is known as the *mycelium*

Fig. 1.—Hyphae. 1, *Penicillium* spore (shaded) producing a mycelium, × 500; 2, hypha of *Rosellinia arcuata*, × 500; 3, hypha of *Polyporus molliculus*, with clamp connection, × 500.

(G., *mykes*, a fungus) of the fungus (Fig. 1). The mycelium is the vegetative part of a fungus.

Hyphae may vary in colour, but their simple structure does not permit of much variation in shape. Consequently, it is not possible, in general, to identify a fungus by means of its hyphae only. In some groups the hyphae exhibit peculiar characters which allow them to be classified as belonging to particular families, as, for example, the swellings on the hyphae of *Rosellinia* (Fig. 1), and the clamp connections of the *Basidiomycetae* (Fig. 1), but these distinguishing features do not differentiate between species. On the other hand, the aggregate of hyphae belonging to a fungus—

[1] The unit of microscopical measurement is the one-thousandth part of a millimetre, that is, about one twenty-five-thousandth part of an inch. This is called a micron, and is denoted by the Greek letter mu (μ). Thus the average diameter of a fungus hypha is about 5 μ.

its mycelium—may assume forms which are peculiar to the species, and so enable a mycologist to identify a disease when the fructification is not present.

The mycelium of a fungus permeates the part of the plant or the substance on which it is feeding, its hyphae penetrating into the tissues and gradually consuming them. In some instances, especially in the case of saprophytic species, masses of mycelium in strands or sheets are also produced externally over the rotting wood or decaying leaves, or in the soil. In other cases the mycelium is entirely confined within the decaying tissues, and only approaches the surface in order to produce its fructification. The latter is especially the case with strictly parasitic fungi which attack leaves, though even among these the mildews form a white external mycelium.

Fig. 2.—*Sclerotium* (*Mylitta*) *ligulatum*, × $\frac{2}{3}$; found on up-country tea estates in Ceylon.

In some species of fungi the external mycelium forms definite cords, enclosed in a tough rind or cortex. Such cords are called *rhizomorphs* (G., *rhiza*, a root; *morphe*, shape). The rhizomorphs of the Honey Mushroom resemble black leather boot-laces. Again, some species form closely compacted balls of hyphae, with thickened walls, enclosed in a black or brown cortex, which become free from the rest of the mycelium. These balls are known as *sclerotia* (G., *skleros*, hard). The sclerotia found in the rice plant are about the size of a pin's head or less, while the black sclerotia found in white ants' nests may be as large as a hen's egg. These sclerotia are specialised parts of the mycelium which enable it to survive a period of drought. When placed in a damp situation they develop either a new mycelium or the fructification of the fungus.

Reproduction

Fungi do not produce seeds. They are propagated by spores. The seed of a flowering plant is a highly organised structure, generally differentiated into seed coats, seedling leaves, and a rudimentary shoot and root. A fungus *spore*, on the other hand, is merely a spherical, oval, or elongated case, with a thin wall, filled with protoplasm. It may be divided up by cross partitions (septa), which probably serve to keep the wall rigid, but it does not exhibit any differentiation comparable to that of a seed. When a spore meets with favourable conditions it germinates by growing out a hypha which develops into a mycelium.

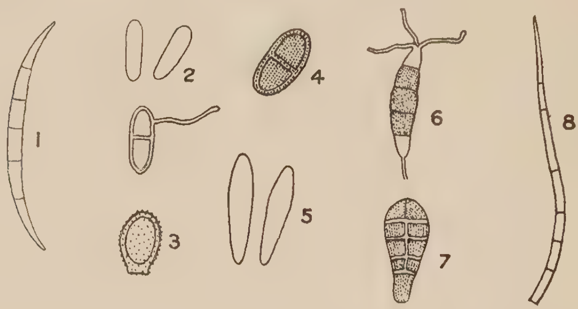

Fig. 3.—Forms of spores. 1, *Fusarium*, ×600; 2, *Colletotrichum Camelliae*, ×500, the lower spore germinating; 3, *Fomes lucidus*, ×800; 4, *Botryodiplodia Theobromae*, ×400; 5, *Macrophoma theicola*, ×500; 6, *Pestalozzia palmarum*, ×800; 7, *Macrosporium commune*, ×500; 8, *Cercospora Theae*, ×300.

Fungus spores are, in general, very minute. Spores of the common moulds which develop on boots, etc., are about 4 μ in diameter. Spores of agarics (toadstools) average about 8 μ. But some spores are up to 100 μ long. They are usually produced in large numbers, and in the case of some fungi they form masses of white, or brown, or black powder. As a rule they are readily dispersed by the wind, washed away by rain, or conveyed from place to place adhering to insects, animals, etc.

Fungi are classified according to the manner in which the spores are produced, and the shape and colour of the spores.

Hyphomycetae

In the simplest form of reproduction a hypha bears a branch, from which spores are budded off at the apex or along the sides. In general, these branches stand erect. In some species a single spore is produced at the apex, and after that has fallen the branch grows further and develops another; in other species the spores are produced in succession at the apex, so that they stand in chains. These spores, which are borne free, *i.e.* not in a case or receptacle, are known as *conidia*, and the branch which bears them is called a *conidiophore* (G., *konis*, dust; *phoreo*, I carry). If the mycelium of the fungus is internal, *i.e.* within a leaf, stem, etc., the conidiophores burst through the outer tissues of the host plant and emerge into the air before producing conidia. They often stand side by side in large numbers, covering the surface of the host with a velvety pile.

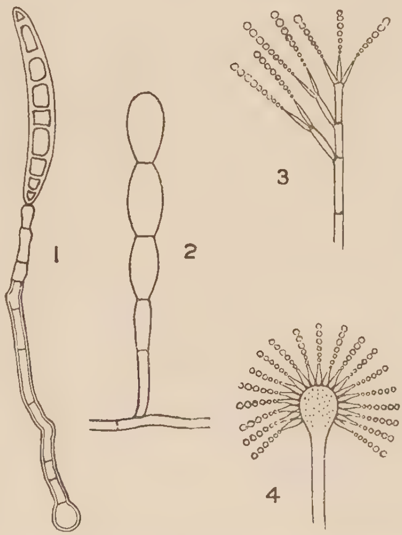

Fig. 4.—Conidiophores and conidia. 1, *Helminthosporium Hereae*, ×300; 2, *Oidium*, ×250; 3, *Penicillium*, ×250; 4, *Aspergillus*, ×250.

Conidiophores may be simple, *i.e.* unbranched, or may bear lateral branches in whorls, after the manner of the cotton tree, or may divide into branches which again divide until a bushy head results. Some are inflated at the apex and bear chains of conidia all over the swelling. Though the structure is relatively simple, there is a bewildering variety of form, all possible methods of branching being represented.

The fungi of this class constitute what are usually known as "moulds." They are divided into genera (groups of species), according to the shape and mode of branching of the conidiophore and the shape, colour, and arrangement of the conidia.

Helminthosporium has a simple conidiophore which bears septate conidia singly at the apex: some species of *Helminthosporium* are parasitic. *Oidium* has a simple conidiophore which bears an apical chain of conidia. In *Penicillium* the conidiophore branches towards the apex, the branches standing more or less parallel to one another, and producing chains of conidia. In *Cercosporella* (Fig. 15) the conidiophore branches repeatedly, and each branch bears a long, septate conidium. The conidiophore of *Aspergillus* terminates in a spherical head which bears chains of conidia all over it, only one row being shown in the figure. *Penicillium* and *Aspergillus* include the common green and

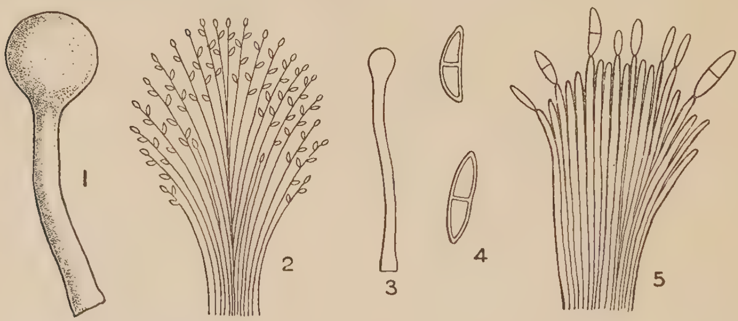

FIG. 5.—1, *Stilbum nanum*, ×50; 2, Conidiophores and conidia of *Stilbum nanum* (diagrammatic), ×350; 3, *Didymostilbe Coffeae*, ×50; 4, conidia of same, ×600; 5, head of same, ×500.

yellow moulds which develop on boots, etc., during wet weather.

In certain forms which belong to this group the individual conidiophores, instead of remaining separate, unite to form a column, or stalk, and separate again at the apex to produce conidia. *Stilbum* and *Didymostilbe* have a cylindrical stalk and a globose head, which is formed by the separated conidiophores and their conidia.

MELANCONIACEAE

In the foregoing class the conidiophore with its conidia, *i.e.* the reproductive part of the fungus, projects into the air, and is exposed to the vicissitudes of the weather and

the attacks of insects at all stages of development. Thus, although this method of spore formation ensures a rapid distribution of the conidia by wind, etc., it lacks one important detail, viz. the protection of the spores until they are mature. This is secured in the next class, the *Melanconiaceae*, in the following manner:

The fungus, in general, lives entirely within the host plant. When it is about to produce spores it forms an interwoven mass of mycelium, a *stroma* (G., *stroma*, a mattress), just below the surface of the host,—for example, beneath the epidermis of a leaf. On the outer side of this stroma short erect stalks, *basidia* (L., *basidium*, a small pedestal), are produced, and at the apex of each basidium a spore, or a chain of spores, is budded off. As the development of the spores advances, the epidermis is pressed outwards and ultimately splits; and the mature spores are then exposed, usually more or less in a heap or pustule. Such a fructification is called an *acervulus* (L., *acervus*, a heap).

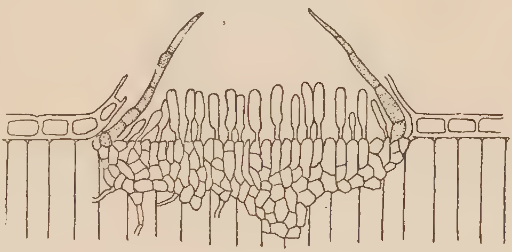

FIG. 6.—*Colletotrichum Camelliae*, section through an acervulus, showing setae and conidia. ×350.

To this group belongs *Gloeosporium*. In one species, *Gloeosporium alborubrum*, which is parasitic on *Hevea*, the acervuli form pink or white masses of spores. When the acervulus of a *Gloeosporium* is surrounded by bristles, or *setae* (L., *seta*, a bristle), it becomes a *Colletotrichum*. Many so-called species of *Gloeosporium* are merely acervuli of *Colletotrichum* which have not developed setae. In both these genera the spores adhere to one another and form a waxy-looking mass, which probably persists until the spores are dispersed by rain or carried away adhering to insects. Species of both genera are responsible for a large number of plant diseases, including many fruit rots.

The group derives its name from one of the earliest known genera, in which the exposed spores appear as masses of black powder (G., *melas*, black; *konis*, dust).

These spores are usually known as conidia, no special term having been adopted for them.

Sphaeropsideae

This class exhibits a further advance in the method of protection of the spores. When the period of fructification arrives, some of the hyphae of the fungus are interwoven and fused together to form a definite hollow structure in which the spores are produced. This is most generally pear-shaped (pyriform), or globose with a conical apex. The wall of this receptacle bears closely packed basidia on its inner side, and spores are produced on these, as in the *Melanconiaceae.* The fructification differs from that of the latter group in that the basidia and spores are produced in a closed receptacle, whereas in the *Melanconiaceae* they are produced on an indefinite stroma, which is covered by the tissues of the host.

This fructification is known as a *pycnidium* (G., *pyknos*, compact), and its spores should be called pycnospores. The wall of the pycnidium may be black or brightly coloured, yellow, red, etc. The apex of the pycnidium is usually perforated by a small pore when mature, and the apical part is called the *ostiolum* (L., *ostium*, a door). The spores when ripe are extruded through the ostiolum.

When the mycelium of a fungus is wholly internal its pycnidia may be built up entirely within the tissues of the host plant, only the ostiolum breaking through the surface. Such pycnidia are said to be immersed. In other species the pycnidia may partly protrude from the host when mature, or they may be superficial, *i.e.* built up from the beginning on the surface of the host. The pycnidia may be separate from one another, or may be united by a compact mass of fungus tissue. In the latter case the mass of fungus tissue is known as a *stroma.*

To this group belong the genera *Phoma*, *Phyllosticta*, and *Diplodia*. *Phoma* and *Phyllosticta* have minute pycnidia containing continuous (*i.e.* not divided or septate) spores, which occur on stems and leaves of living plants; the distinction between them is somewhat arbitrary. *Diplodia* has black, oval spores with a median septum (Fig. 3); if

the pycnidia are distinct the species is *Diplodia*, but if they are united into a stroma it becomes *Botryodiplodia*. Here, again, the distinction is an arbitrary one, as the same fungus may occur in both forms, as is the case with *Botryodiplodia Theobromae*, which causes root disease in tea and Die-back in rubber. *Macrophoma theicola* also belongs to this class; it has the same structure as a *Phoma*, but its spores are much larger (Fig. 7).

Pestalozzia palmarum, another member of either this group or the *Melanconiaceae*, differs from the foregoing in the shape of its spores. These are spindle-shaped, with a short stalk at the basal end and three filaments, or setae, at the apex; they are divided by four cross walls and are consequently five-celled, the three middle cells being dark-coloured and the terminal cells hyaline (Fig. 3).

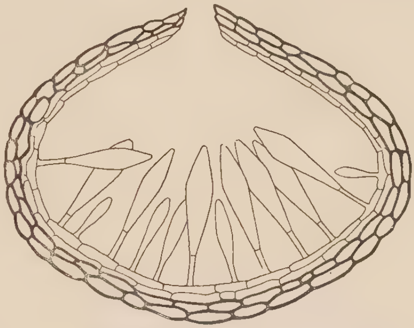

Fig. 7.—*Macrophoma theicola*, section through a pycnidium, showing the spores. ×450.

Pyrenomycetae

In this class of fungi the method of formation and protection of the spores attains its highest development. The fructification in external appearance resembles a pycnidium, and like the latter it may be immersed, or superficial, or embedded in a stroma. But internally it is quite different. It is not lined with basidia, but from the wall there arise elongated closed cells which are known as *asci* (G., *askos*, a wine-skin). The most general shape of an ascus is that shown in Fig. 8, which is called clavate, but they may be ellipsoidal or spherical. The ascus is at first filled with protoplasm, from which a number of spores (ascospores), usually eight, are formed. In some species slender filaments, *paraphyses* (G., *para*, beside; *physis*, growth), arise with the asci from the wall of the fructification. This type of fructification is known as a *perithecium*

(G., *peri*, about ; *theke*, a case, an old term for an ascus). It is usually a pyriform or spherical receptacle, closed except at the apex, where the wall is perforated by a pore (ostiolum). When the ascospores are mature the asci either rupture at their apices or deliquesce, and the spores are extruded through the ostiolum.

To this class belong the numerous species of *Nectria*, some of which are parasitic, though many which have been regarded as the cause of disease are merely saprophytic ; the perithecia are usually superficial and brightly coloured,

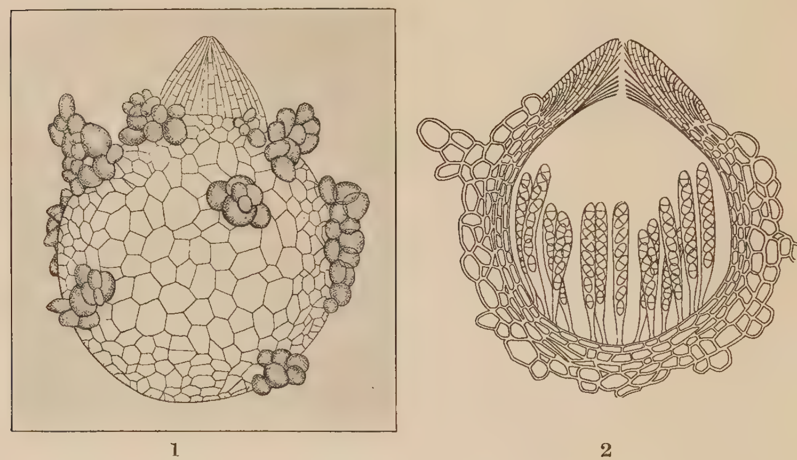

FIG. 8.—1, *Nectria haematococca*, ×150 ; 2, section of the same, showing asci and ascospores. ×150.

and the ascospores are transparent (hyaline) and divided transversely by a septum. In *Rosellinia* (Fig. 48) the perithecia are superficial, black, and brittle (carbonaceous), and the ascospores are dark brown or black, and continuous (not septate). In *Guignardia Theae* the perithecia are embedded in the tissue of the tea leaf, and in *Desmotascus neglectus* they are similarly embedded in the cortex of the tea stem. *Aglaospora aculeata* has carbonaceous perithecia which are embedded in tea stems, the ostiola projecting like black thorns ; its ascospores are long and have up to eleven septa. In *Ustulina zonata* the perithecia are embedded in a black, brittle stroma, forming the well-known crust-like fructification (Fig. 53).

Polymorphism

In the foregoing sections four classes of fungi, differentiated by the character of the fructification and the method of formation of the spores, have been briefly described. On first considerations, they appear to be classes as distinct as birds, and beasts, and fishes, and so they were thought to be when mycology was first studied. But it is now known that the species in these different classes do not necessarily constitute separate entities, but that a species in one class may be merely a form, or stage, of a species in another class. This is sometimes found a difficult idea to grasp, because it is so different from everyday experience based on flowering plants. If one sows the seeds of a rose, he does not expect them to produce lilies. But if one sows the spores of a *Nectria*, which is a Pyrenomycete, it is almost certain that the first product will be a Hyphomycete of some kind.

Restricting our view to the four classes already mentioned, the *Pyrenomycetae* are regarded as the highest type of fructification. Any species of this class, *e.g.* a *Nectria*, is known as the perfect stage of that particular fungus. If the ascospores of that fungus are sown in a proper medium they may give rise to conidiophores and conidia, or acervuli, or pycnidia, before finally reproducing the perithecia or ascigerous stage. These earlier forms—*Hyphomycetae*, *Melanconiaceae*, and *Sphaeropsideae* — are known as imperfect stages.

A " perfect " fungus may have one or more " imperfect " stages, that is, a perithecial fungus, a *Sphaerella*, may have a stage in which it appears as a *Phoma*, another in which it is a *Gloeosporium*, and yet another in which it is a Hyphomycete. Theoretically, every perithecial fungus (Pyrenomycete) should have one or more imperfect stages; and, conversely, every imperfect fungus should be a stage of some perfect (perithecial) fungus. Very many of these related stages have been discovered, but there are also many species which have never been known to produce more than one stage. It is probable that these latter fungi have lost the power of producing other stages.

This occurrence of several forms in the same species is known as polymorphism. In studying a parasitic fungus it

is usually necessary to ascertain under what different forms it appears, or, in other words, to ascertain the life-history of the fungus.

"Imperfect" forms of fructification usually produce short-lived spores, which serve to propagate a fungus rapidly under favourable conditions. The spores of the perithecial stage, ascospores, are generally more resistant to desiccation and cold, and hence enable a fungus to survive unfavourable conditions. Consequently, in temperate climates conidia are often known as summer spores, and ascospores as winter spores.

Discomycetae

Though the classes already described include a large proportion of the parasitic fungi, there are several other classes which do not fall into the arrangement outlined, but must be considered separately.

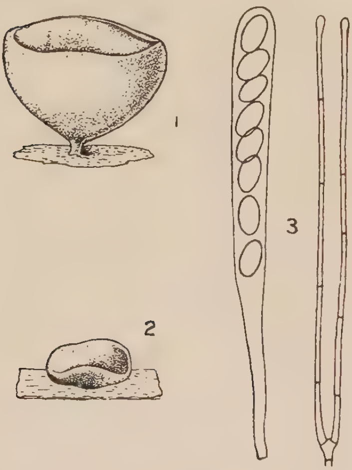

Fig. 9.—1, *Peziza sulcipes*, natural size; 2, *Peziza sarmentorum*, natural size; 3, ascus and paraphyses of *Peziza sarmentorum*, × 300.

The *Discomycetae* are often known as cup fungi, from the shape of the fructification, which in many species of this class resembles a cup. Some are stalked and shaped like a wine-glass, others are sessile (*i.e.* not stalked) and cup-shaped, while others, again, are more widely open and would be more appropriately likened to a saucer. The concavity is lined with asci and paraphyses closely packed side by side, forming an inner layer to the cup in the more concave forms, or almost filling the cavity, so that the upper surface is flat, in the shallower forms. As a rule, each ascus contains eight spores.

This class resembles the *Pyrenomycetae* in that the spores are contained in asci, but differs in having the fructification widely open.

A curious method of ejection of the spores may be easily

observed in the larger species belonging to this class. A sudden alteration in the humidity (or temperature) of the surrounding air causes the fructification to eject its spores in a white cloud. This can be induced by breathing on the fructification, or sometimes by merely handling it; while if the specimens are kept for some time in a closed receptacle, they will "puff" when it is opened.

No species of this class have yet been found to be parasitic on tea, rubber, or coconuts, but a somewhat aberrant genus, *Exoascus*, supplies a species, *Exoascus Theobromae*, which is parasitic on cacao.

Phycomycetae

This class includes the genus *Phytophthora*, which furnishes some of the most serious parasites of tropical cultivations, more especially of rubber, cacao, and coconuts. In temperate climates, *Phytophthora* is commonly regarded as attacking plants which have comparatively soft tissues, and one species is well known as the cause of the most destructive disease of potatoes; but in the tropics that generalisation does not hold good, and species of *Phytophthora* there attack stems which have relatively hard tissues.

The hyphae of a *Phytophthora* are usually stout and have few septa; the mycelium permeates the tissues of the host plant and appears as a white covering on the exterior. This mycelium gives rise to branched *sporangiophores* (often called conidiophores), which bear a *sporangium* (G., *spora*, a seed; *angeion*, a receptacle) at the end of each branch. The sporangia are usually oval with a prominent papilla at the apex. These sporangia fall off, after the manner of conidia, and, if they fall into water, their contents divide up into a

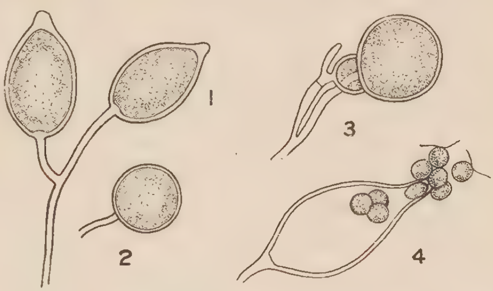

Fig. 10.—1, Sporangia of *Phytophthora Faberi*, ×400; 2, a resting conidium of the same, ×400; 3, Oogonium (upper) and antheridium (lower) of *Phytophthora Meadii*, ×400; 4, escaping zoospores of *Phytophthora Meadii*, ×400.

number of small masses of protoplasm, each furnished with two slender threads or cilia; these masses of protoplasm are known as *zoospores*. The papilla at the apex of the sporangium then dissolves or bursts, and the zoospores emerge and swim about in the water by means of their cilia. After some time they round off, acquire a cell wall, and subsequently germinate by growing out a hypha. Thus, it is essential, for the regular development of a *Phytophthora*, that the sporangia should fall into water. However, a mere film of water on a leaf or stem is quite sufficient, and an attack of a *Phytophthora* disease may follow a succession of heavy dews. As is well known, attacks of *Phytophthora* on rubber and cacao are largely dependent upon weather conditions.

It will be noted that a sporangium is a cell which is produced in the same way as a conidium, but in which the contents divide into a number of spores, which are set free by the rupture of the sporangium wall. A zoospore is a spore which is able to move about under its own power.

In some instances, instead of sporangia, spherical spores are produced which do not form zoospores, but presumably germinate by the production of a hypha. These spores are known as resting conidia.

In addition to the method described, *Phytophthora* also produces spores by a sexual process, *i.e.* by the fusion of the contents of two specially differentiated structures. One of these, which is known as the egg-cell, or *oogonium*, is a spherical swelling formed like a conidium at the apex of a hypha. The other, known as the *antheridium*, usually rises from the same hypha as the oogonium, and becomes closely applied to the latter. A short tube is then pushed out from the antheridium into the oogonium, and the contents of the former pass through the tube and fuse with the contents of the latter. In consequence of this fusion, the oogonium is fertilised and becomes an *oospore*. The oospore subsequently germinates by forming zoospores or by growing out a hypha.

Oospores are usually thick-walled, and constitute resting spores which carry the fungus through seasons unfavourable to its growth. The sporangia, with their zoospores, on the

other hand, serve to propagate the fungus rapidly during wet weather.

In *Phytophthora Faberi* Maubl., which causes canker and pod disease of rubber and cacao, oospores have not yet been observed. In *Phytophthora Meadii* McRae, which causes Black Thread and pod disease of rubber, the hypha which bears the oogonium grows through the antheridium, so that the empty antheridium is left surrounding the stalk of the fertilised oospore.

Basidiomycetae

This class includes the plants which are the more generally recognised as fungi by the layman, viz. the large fleshy or woody bracket fungi (*Polypori*), and the better-known toadstools and mushrooms (*Agaricaceae*).

The shape of an agaric is typically that of the common mushroom. The fructification consists of a cap, or *pileus* (L., *pileus*, a cap), on a central stalk. On the under surface of the cap, thin vertical plates, known as *gills*, radiate from the stalk to the margin.

The gills are covered with cylindric or clavate cells, closely packed together, perpendicular to the plane of the gill and forming a continuous palisade tissue. Each of these cells bears four short projections, on each of which a spore is produced. These special cells are known as *basidia*, the four projections as *sterigmata* (G., *sterigma*, a prop), and the spores as *basidio-spores*. The surface layer of basidia is known as the *hymenium*. It will be noted that the term basidium has already been employed to denote a different structure in the *Melanconiaceae*; this is a defect in mycological nomenclature for which no one has yet proposed a satisfactory remedy.

The spores are produced free at the ends of the basidia, and in that respect they resemble the conidia of the *Hyphomycetae*. There are, however, differences in their development which show that the resemblance is only superficial. To obtain the spores, the cap should be cut off and placed, gills downwards, on a sheet of paper; in a few hours, a thick layer of spores is deposited on the paper, marked with the pattern of the gills. The colour of the spores may be white, red,

yellow-brown, purple-brown, or black, or in a few species, green or slate-coloured, etc.

The majority of the *Agaricaceae* are saprophytic. *Armillaria fuscipes* causes root disease of *Acacia*, and probably of tea (Fig. 67). *Marasmius equicrinis* (Fig. 11), which has an aerial mycelium resembling horse-hair, is the Horse-hair

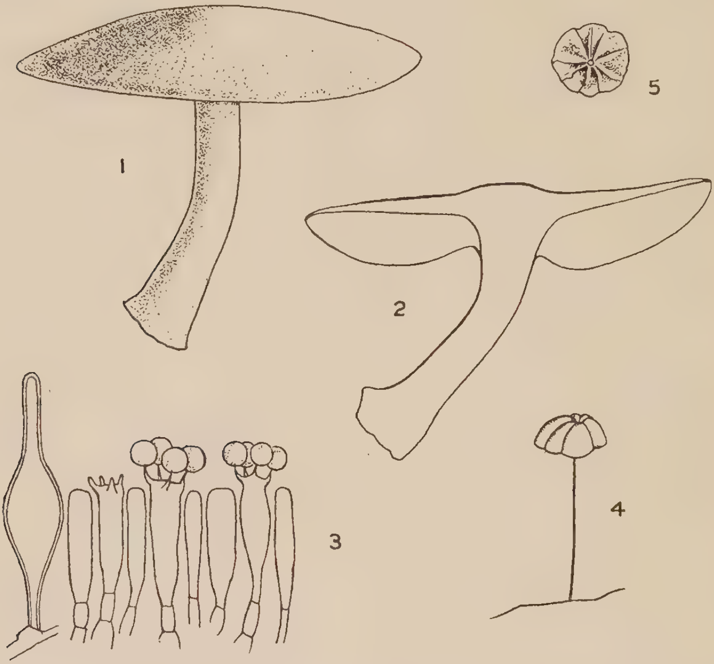

Fig. 11.—1, *Oudemansiella apalosarca*, small specimen, natural size; 2, longitudinal section of same, showing the gills, natural size; 3, basidia and a cystidium of the same, ×250; 4, *Marasmius equicrinis*, ×1½; 5, the under side of the pileus of *Marasmius equicrinis*, showing the gills, ×1½.

Blight of tea and rubber in the East; while one of the Thread Blights is the mycelium of *Marasmius pulcher*.

The *Polypori* are the most important section of this group from the planter's point of view, as very many of them are parasites or facultative parasites. A few of them have a central stalk, like an agaric, but in the majority the pileus grows out laterally from the host plant, and is either shortly stalked, or more generally sessile (*dimidiate*). In the latter case it projects from the host like a bracket, and

hence these species are known as bracket fungi. The lower surface of the pileus does not, in general, bear gills or plates, but is covered with vertical tubes (*pores*), close-set side by side, so that on looking at the lower surface one sees a number of holes, varying in size and shape according to the species. These pores are lined with a layer of basidia similar to those on the gills of an agaric. The tissue between the layer of pores and the upper surface of the pileus is referred to as the context (Plate III.).

Among the genera of the *Polypori* are *Polyporus*, *Fomes*, *Polystictus*, and *Trametes*. These grade into one another so closely that it is difficult to decide the limits of each genus. *Polyporus* contains fleshy, somewhat soft, species, often of great size and irregular in shape, which produce one layer of pores and then decay. In *Fomes* the pileus produces successive layers of pores on the under surface, so that in old examples a section of the fungus shows several strata of pores : in temperate climates it is customary to consider that one layer of pores is produced every year, but there is no doubt that, in the tropics, these layers represent the growths during successive periods of wet weather, probably of only a few weeks' duration. Whether one finds several pore layers in *Fomes* or not, depends obviously on the age of the specimen. Failing their occurrence, the hard bracket fungi are classed as *Fomes*. *Polystictus* includes species of the same general form as *Polyporus* and *Fomes*, but usually thin and flexible.

Polyporus mesotalpae (Fig. 63), which causes root disease of tea, has a massive central stalk, while *Polyporus interruptus* (Fig. 65), the cause of another tea root disease, is usually resupinate (*i.e.* lies flat on the host plant). *Fomes applanatus* (Figs. 61, 62) and *Fomes lamaoensis* (Plate III.) are typical *Fomes*, very hard, bracket-shaped, and frequently with several pore layers. But *Fomes lignosus*, though bracket-shaped, is merely woody, and seldom bears more than one layer of pores (Plate III.).

Sometimes these *Polypori* occur without a pileus, in the form of a plate, studded with pores, lying flat on the host plant. This is known as a *resupinate* form (L., *resupinatus*, lying on one's back). Many brackets of *Polyporus* or *Fomes* have a resupinate part running down the surface of the

host plant from the projecting pileus, but resupinate forms also occur, unattached to any bracket. These latter resupinate forms are classed in the genus *Poria*. In some cases they are known to be resupinate forms of species of *Fomes*, *Polyporus*, etc., but there are many which apparently do not exist in any other than the *Poria* form. When *Fomes lignosus* fructifies on the under side of a rubber log, it assumes a *Poria* form, but that is easily recognised as being the same as the bracket form of that species. On the other hand, *Poria hypobrunnea* (Plate III.) and *Poria hypolateritia* (Plate II.) have been found only in the form of flat plates, never

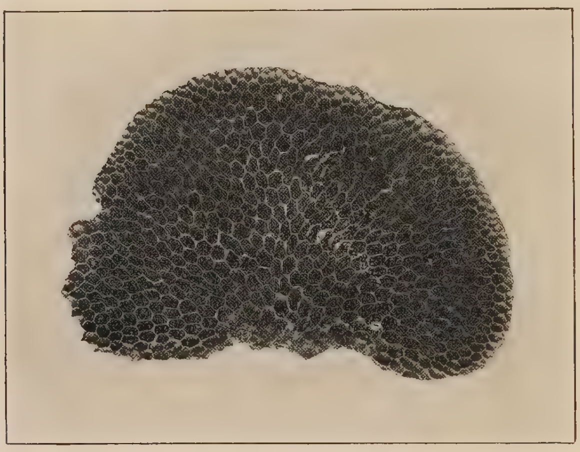

FIG. 12.—*Hexagonia apiaria*. $\times \frac{2}{3}$.

in bracket shape; consequently, these are regarded as true Porias.

A common tropical genus of this class has large hexagonal pores, and has been named *Hexagonia*. One species, *Hexagonia discopoda*, is common on dead branches of rubber trees. It is believed to be merely saprophytic.

In the genus *Irpex*, the hymenium is borne on projecting teeth on the lower surface of the pileus. These teeth, in the commoner tropical species, are usually flattened from side to side, more or less triangular, and pointed. One very common saprophytic species, *Irpex flavus*, is yellow, thin, but somewhat tough, and usually resupinate with a free projecting (dimidiate) edge: it is common on dead wood,

dead bamboos, etc. Another species, *Irpex subvinosus*, causes a root disease of *Tephrosia candida* and tea ; it is blue or purple-blue at first, but fades to ashy or fawn-coloured (Fig. 66).

In many of the *Basidiomycetae*, the hymenium is a flat level surface, without gills, pores, or teeth. Such fungi are usually resupinate, and grow along the lower surface of logs, or of branches of living trees, so that the basidia which form the hymenium point downwards. They appear as thin, coloured patches, white, pink, yellow, etc., on the surface of the host. One genus of this form is *Corticium* ; *Corticium salmonicolor* (Plate II.) is the fungus of Pink Disease, and appears as a thin, pink sheet overlying the bark of tea and rubber. In another, *Hymenochaete*, the fructification is usually resupinate, though some species are dimidiate ; it owes its name to the fact that numerous very minute bristles (setae) project from the hymenium.

The genus *Exobasidium* includes species which differ completely in appearance from those of most of the preceding genera. They are all strictly parasitic, and usually cause swellings and distortions of the part of the host which is attacked. The mycelium lives within the plant tissues, and the fructifications consist of groups of basidia which burst through the epidermis of the host and form a powdery patch. To this genus belongs *Exobasidium vexans* (Fig. 18), which causes Blister Blight of tea, the name of the disease being due to the white or red blisters which are produced on the leaves and stems. *Exobasidium zeylanicum* attacks *Rhododendron arboreum* in Ceylon, and the affected leaves bear pink or white spherical galls, like small peaches, up to an inch or more in diameter. Similarly, *Exobasidium Cinnamomi* causes outgrowths resembling stags' horns on cinnamon.

When the spores of an agaric or a polyporoid fungus are mature, they fall down from the hymenium, and are dispersed by the wind. The larger *Fomes* produce millions of spores which are often deposited as a brown powder on neighbouring grasses, etc. In many cases they are also deposited on the upper surface of the pileus, and it is believed that they are conveyed to that position by air currents.

Uredinaceae

The fungi of this class, at least in one stage, are known as Rusts. It is unfortunate that the latter name should have been applied in the Eastern tropics to a disease, Red Rust of tea, which is caused by an alga, and to the effect on tea of an insect, Scarlet Mite (*Brevipalpus obovatus*). All the species of this class are strictly parasitic, and many are responsible for serious diseases of agricultural crops, *e.g.* wheat, barley, beans, etc. No rust fungus has yet been found to attack tea, rubber, or coconuts, but, on the other hand, the coffee plantations of Ceylon were ruined by a rust fungus, *Hemileia vastatrix*.

A rust fungus has, in general, three forms. The first of these is known as the *aecidium* or cluster cup stage (? G., *oikidium*, a little house). This takes the form of minute cups embedded in the leaf or stem. As a rule, the cup has a white, recurved margin, and a yellow centre which consists of chains of spores arising from the base of the cup. If these spores are sown on the proper host, they give rise to another form, the *uredo* (L., *uredo*, a blight). In this form the mycelium in the host plant forms a weft of hyphae beneath the epidermis, from which arise short stalks bearing oval or globose spores. The epidermis then ruptures and exposes the masses of spores. As the uredospores are usually brown, the groups of spores (*sori*, G., *soros*, a heap) have the appearance of iron rust—hence the common name of these fungi. If now the uredospores are sown, they may produce a third form, in sori like the uredo, but usually dark or black, and with spores which vary in shape according to the genus; in some genera the spores nearly resemble the uredospore, but in most genera they are variously septate. The spores of this third form are known as *teleutospores* (G., *teleute*, an end).

When the teleutospores germinate they produce a basidium which bears minute secondary spores. If the latter infect the proper host plant they give rise to a mycelium, and the cycle begins anew.

Any given stage of a rust is, as a rule, confined to one host plant, or to a few closely related hosts. A rust on coffee, for example, would not be likely to attack tea. There

is, however, the peculiarity that many species of rusts change their hosts for different stages. The classical example is that of *Puccinia graminis*, a rust of wheat; the aecidium stage of this species lives on the Barberry (*Berberis vulgaris*), while the uredo and teleutospore stages occur on the wheat plant. Very many cases of this phenomenon, which is known as heteroecism (G., *heteros*, another; *oikos*, house), have been proved to exist in temperate climates, but tropical species have not been investigated in this respect.

CHAPTER II

LEAF DISEASES

In the case of the majority of cultivated plants the effect of a leaf disease may be said, with some degree of justification, to be indirect. In general, a fungus which attacks a leaf kills or modifies the tissues over a limited area, the extent of which is indicated by a change in colour or texture, or in some cases the diseased patch may drop out. Now the leaf is the factory in which the plant manufactures the material required for building up new leaves, new wood, etc. Consequently, the immediate effect of a leaf disease is to diminish the area of green tissue available for carrying on that work, and so to decrease the quantity of food material manufactured to a degree proportionate to the amount of leaf area destroyed. The ultimate effect produced by this food shortage may be a decrease in the quantity of new foliage and wood, or a general retardation of the growth of the plant. In some diseases, as in the coffee leaf disease, caused by *Hemileia vastatrix*, the leaves which are attacked by the fungus may fall off; and the periodic repetition of this defoliation may finally result in the death of the plant.

The tea planter is perhaps more alert to notice the occurrence of leaf diseases than is the grower of other plants, for the very obvious reason that the tea bush is cultivated for the sake of its leaf. The leaf is the crop. Hence a leaf disease of tea not only affects the crop at some future date by its indirect effect on the bush, but, if it attacks the young leaf, immediately and directly reduces the amount of leaf which can be utilised for the manufacture of tea. The list of leaf diseases of tea, now that the search-light of local investigation has been directed upon the tea bush, is rapidly assuming portentous dimensions, but, except for the Blister

Blight of Northern India, it cannot be said that any of them is of a character serious enough to arouse general alarm.

The methods which have been proposed for the control of leaf diseases of tea are—

(1) Plucking and burning diseased leaves.
(2) Manuring and general cultivation.
(3) Spraying.

The first of these methods is perhaps the only direct method applicable to a cultivation in which regular periodic spraying with fungicides is considered either impracticable or impolitic ; and it has been the more readily recommended in the case of leaf diseases of tea because plucking is already in vogue as the only way of obtaining the crop. It has been carried out where small areas have been badly attacked, and in nurseries, but it has seldom been adopted on a large scale, and no estimates of the cost are available. It is most obviously to be recommended when the bushes are attacked soon after pruning.

Carruthers, in 1900, made some small-scale experiments on this point in Ceylon, on an estate at an elevation of 4000 feet. "The bushes first selected had gone 12 months from pruning ; they were big healthy bushes with little, if any, disease apparent. All leaves with any spot due to fungus or insect were taken off, as it was impossible to instruct coolies as to any special blight. A quick podian plucked the leaves, and was closely watched to see that no leaves with any spot were left. The time taken was nearly 6 minutes per bush, or 10 bushes per hour, and about 60 leaves were taken from each bush." "A second series of bushes in a field which had gone 22 months from pruning were treated in the same way ; the bushes were healthy, but the leaves were spotted, and a large quantity of dead leaves were on the ground. In this case the time taken was 41 minutes to a bush, and nearly 3000 leaves were plucked from each bush ; in some cases 90 per cent of the leaves were taken off."

Watt and Mann record that "On Tingri (Dibrugarh), where a bad attack (of Grey Blight) has been successfully dealt with, all pluckers were supplied with a second bag in which blighted leaf was put as they went round the garden,

and this blighted leaf was paid for at the same rate as the leaf for manufacture, and it could then be burnt. By a somewhat similar method an epidemic attack was successfully dealt with on another garden in Dibrugarh recently." These authors state, with regard to Grey Blight: "The only need is systematic and thorough removal of the blighted leaves in the spring and burning them. If this is left till the bushes become seriously affected in the middle of the season, more drastic measures may have to be adopted if anything is to be done at all."

Anstead and McRae have recorded that, in one instance, in dealing with an outbreak of Brown Blight, 17,269 lb. of diseased leaves were collected and burnt from an area of twenty acres in three pickings, while over the whole estate 40,122 lb. of diseased leaves were brought in and burnt during the course of the year. Cash payments were made per given weight of leaf collected, and the work was done by special coolies, not by the pluckers.

The opinion strongly held in Ceylon—that the common leaf diseases of tea are less prevalent where balanced manuring and cultivation are systematically carried out—is based on the planting experience of the last twenty years, and appears to be well founded. Towards the close of the last century leaf diseases of tea were of general occurrence, and so much in evidence as to cause considerable alarm, but, at the present day, though there is always some Grey Blight and Brown Blight to be found on a tea estate, the damage done is in the majority of cases negligible. The period is too long to permit the suggestion that the difference in the intensity of leaf diseases is to be attributed to varying weather conditions, and there does not appear to be any escape from the explanation that the diminution of disease has been brought about by the extensive, practically universal, adoption of manuring and cultivation during the last twenty years. No experimental data on the influence of different manures in preventing the attack of leaf diseases, or in minimising their effect, can be given, as the only differential manurial experiments now in progress in Ceylon are carried out on tea of different jats. It may, however, be noted that the earlier manuring, *ante* 1900, consisted principally of forcing the bushes by nitrogenous manures, and

the records would appear to show that this favoured the development of leaf diseases. In Japan, it is stated, Grey Blight is made worse by nitrogenous manuring.

In India, experience would seem to indicate that the commoner leaf and stem diseases can be controlled by adequate manuring. The publications of the Indian Tea Association state that Brown Blight, Grey Blight, Die-back, and Red Rust may be directly traced to deficiencies in the soil, and that Die-back and Brown Blight are diseases of weak plants.

Spraying tea for leaf disease has been frequently advocated but has not been widely adopted. Indeed, it might perhaps be said that except in the case of disease in nurseries, and in the treatment of Blister Blight in India, spraying is unknown, and reliance is generally placed on the methods already described. It must be admitted that, on the average tea estate in Ceylon, there are many obstacles in the way of spraying, not the least of which is the difficulty of securing an adequate supply of water without an excessive expenditure of labour. And it is practically impossible to spray effectively unpruned tea planted 4 feet by 4 feet.

A further objection to the general adoption of spraying for diseases of tea in any country is based on the fear that the fact may be utilised by its competitors in the world's markets to its detriment. The most effective fungicidal sprays are those which contain copper in some form, and if such sprays are used there is a possibility that the manufactured tea might be thought to contain copper to an amount which would be prejudicial to the health of the consumer. This question has been investigated in India by Annett and Kar, with the following result:

A certain area of an estate was sprayed with Bordeaux mixture. Nine days later the tea was plucked, and 80 lb. of made tea was manufactured from the sprayed leaf. An equal quantity was taken for comparison from the tea made from the leaf plucked on an unsprayed area. On analysis the tea from the sprayed area was found to contain half a grain of copper per lb., while that from the unsprayed area contained one-twelfth of a grain of copper per lb. A sample of tea bought on the open market was found to contain one-eighth of a grain of copper per lb. As an additional

test, eight teaspoonfuls of sprayed tea were infused as in the ordinary household method of making tea, the total amount of liquid being equal to the contents of eight breakfast cups. The whole of this volume contained only ·0002 grams of copper, an inappreciable amount. Unsprayed tea infused in this manner did not show any copper. The amount of copper found in sprayed tea is therefore not likely to cause any injury to the consumer. As the authors quoted point out, ordinary foods usually contain small quantities of copper, which in the case of cocoa may be nearly a quarter of a grain per lb.

It is, however, in dealing with pruned tea that spraying is likely to be most effective, and in such cases there is no danger of any copper being present in the manufactured article. For stem diseases, such as Pink Disease, or stem and leaf diseases, such as Black Rot and Red Rust, spraying with Bordeaux mixture is a necessity, but it should be done after the bushes have been pruned, to kill spores or fungus filaments on the stem. Some of the common leaf diseases, *e.g.* Grey Blight, can attack the old wood, and, consequently, after serious outbreaks of leaf disease, the bushes should be sprayed after pruning. Whether spraying after pruning will ever become a normal practice of tea cultivation depends upon the extent to which leaf diseases of tea increase ; it is quite within the bounds of probability.

Where leaf diseases have been unduly prevalent prior to pruning, the prunings should be burnt. The fungus of Grey Blight in particular, and that of Brown Blight to a lesser degree, flourish on dying tea leaves and prunings, and provide myriads of spores capable of infecting the new growth.

In dealing with leaf diseases in tea nurseries the diseased leaves should be collected and burnt, and the plants then sprayed with Bordeaux mixture. If the plants are weakened by disease in the nursery, they are scarcely likely to make rapid progress when planted out in the field.

In enumerating the diseases of tea in the following pages, it has been considered desirable to attempt a simplification of the subject by separating the diseases which are primarily leaf diseases from those in which the parasite usually attacks both the leaf and the stem, as in Blister Blight and Red Rust, or in which the fungus develops first on the stem and

travels thence to the leaf, as in the Thread Blights. The division, however, is not a rigid one, as both Grey Blight and Brown Blight, which are generally regarded as leaf diseases, often attack the stem.

Grey Blight

(*Pestalozzia Theae* Sawada)

This disease has been known to exist on tea in Northern India since about 1872, but it was not until 1898 that the cause of it was determined. In that year Dr. Watt sent specimens to Kew, where Massee found that the fungus responsible for the injury was a species of *Pestalozzia*. As was only to be expected, the occurrence of a leaf disease on the Indian tea estates occasioned great alarm, and Dr. Watt wrote: "I regard the Grey Blight as very alarming, a disease that if not checked may easily reduce the productiveness of gardens by 50 per cent. It might, in fact, convert Assam from the prosperous province the planters have made it to one of extreme distress." Fortunately, the disease has not proved so serious as was anticipated, though under certain conditions it can cause much damage. In considering these earlier reports it has to be remembered that they deal with the first occurrence of leaf disease on tea, and, in all probability, they relate not to Grey Blight only, but to a number of leaf diseases grouped together under one name.

The characteristic spot of Grey Blight (Plate I., Fig. 1) is irregularly circular or oval, and varies in size from a diameter of one centimetre to almost the entire breadth of the leaf. It may be situated in the middle of the leaf, or extend inwards from the tip or from the margin. The upper surface is concentrically zoned with pale and dark brown, or with pale brown and grey, and is frequently concentrically ridged with slightly elevated ridges. It is covered with minute black points, the fructifications of the fungus, which are also arranged more or less in concentric circles. The spot is at first surrounded by a narrow greenish-yellow zone, or sometimes by a narrow purple zone. On the under surface the spot is greyish brown, less evidently zoned, or not zoned at all. When old the patch becomes grey or greyish white, hence the name Grey

Blight, but this appearance may occur in several other leaf diseases and is not confined to that caused by *Pestalozzia*. The very young, small spots are at first yellow or greenish yellow—another feature which is shared by other diseases.

Though the spot as described above enables the observer to classify his disease as Grey Blight without any possibility of a mistake, very many cases occur in which this characteristic spot is not produced. The affected leaves may bear spots which are uniformly coloured red-brown at first, and grey or white when old, without any trace of zonation, and the black fructifications of the fungus may be scattered irregularly over the surface of the spot. In such cases only a microscopical examination of the spores can decide whether the disease is Grey Blight or not.

In its most general mode of occurrence, Grey Blight attacks the older leaves of the tea plant, and, as the bush, as a rule, is not defoliated by it, the damage which it causes is usually regarded lightly. There must, of course, be some injury to the bush. On every affected leaf the tissue attacked by the fungus, *i.e.* the whole of the discoloured spot, is killed, and that part of the leaf is thereby put out of action as regards the manufacture of plant food. There is therefore less food available, and consequently the amount of flush must be reduced. How far this operates in reducing the crop depends obviously on the number of leaves attacked. The question is by no means a simple one, and is complicated by factors peculiar to tea, *e.g.* the periodic pruning. But as far as is ascertainable from records of yields, etc., Grey Blight on the older leaves has little effect on the vitality of the tea bush, and hence on the crop.

The case is otherwise when Grey Blight attacks the young leaf, as it sometimes does. Here the effect on the crop is direct and immediately evident. The affected leaf is blackened, the patches usually extending from one side of the leaf or from the tip. Frequently the leaf is attacked before it is completely unfolded, and, in consequence of the death of the affected area on one edge of the leaf, it becomes distorted as it completes its expansion. These blackened areas are thinner than the healthy part of the expanded leaf and almost membranous when dry; they frequently break up as the leaf expands. It is not unusual to find

these blackened, ragged areas bordered by a normally-zoned Grey Blight spot, the former having been produced when the leaf was quite young and the normal spot as it grew older.

The Grey Blight fungus can grow on other parts of the plant besides the leaf. It can occur on woody stems, and is often common on the young stems of badly affected bushes. It sometimes attacks the ends of the plucked shoots and kills them back for a short distance, and the repetition of this process has been known to result in the production of a brush of dead shoots at the ends of the young branches. Bernard has suggested that when the shoots are killed back in this manner, the spores of the fungus have been transferred to the shoot by the plucker. The fungus, as far as is known, does not travel from the leaf to the stem in the tissues of the plant. Each leaf spot and each stem spot is the result of a separate infection by spores.

The mycelium of the fungus lives entirely within the host plant, the only outwardly visible part of the fungus being the masses of spores. If the minute black points on the affected leaves are examined with a lens, they will appear as projections open at the top, with a whitish margin round the opening. The spores are produced in masses beneath the epidermis of the leaf, which ruptures when they are ripe and is turned up to form a margin round the black mass of spores. The spores are unmistakable when seen under a microscope. They are narrowly oval, usually with four cross walls dividing them into five cells. The three middle cells are dark coloured, and the two terminal cells hyaline. The uppermost cell bears three long, hair-like threads, and the lowest cell terminates in a short stalk (Fig. 3). There is considerable variation in the length of the spores and the degree of the constriction at the septa (cross walls).

The spores germinate readily, the germination tube originating, as a rule, from one of the dark cells. The growth of the fungus in a nutrient solution containing sugar is remarkably rapid, the surface of the liquid being covered in a few days by a thick, white felt of mycelium dotted with minute, black heaps of spores. This rapid development under artificial conditions leads one to expect that the fungus would prove a more vigorous saprophyte than parasite,

i.e. that it would grow more luxuriantly on dead than on living material; and this is borne out by its occurrence in the field. It develops rapidly on dead branches and leaves of tea; and the leaf spots caused by other fungi, *e.g.* Brown Blight, are frequently attacked by *Pestalozzia*. If healthy leaves of tea are gathered and placed in a closed glass dish, they are fairly certain to develop *Pestalozzia* as they decay. This illustrates the ubiquity of the spores of the *Pestalozzia*, as well as its ability to grow on dead or dying tissues. If *Pestalozzia* is ever considered a serious disease of tea, it will be absolutely necessary to remove all prunings from the field, and preferably to burn them. At Tocklai (India) it has been found that *Pestalozzia* spores are present in the air in greater number than those of any other common fungus which attacks tea.

The occurrence of Grey Blight in India has already been referred to. In Ceylon it appears to have been noted in 1882, but the first mention of it as Grey Blight in that country dates from 1899. Though it excited some attention when first discovered, it is not now considered a serious disease, except when it attacks the flush, and in general no preventive measures are undertaken. The prevailing opinion of the tea planter is that since modern manuring and cultivation have been adopted Grey Blight has become negligible. Practically the same conclusion has been arrived at in India; Tunstall (*Quarterly Journal of the Indian Tea Association*, 1916, p. 74) writes that Grey Blight cannot be regarded as a dangerous parasite.

In Java Grey Blight was recorded as a disease of tea about the year 1906, and, as in other countries, its first appearance in quantity gave rise to much alarm. The view now taken appears to coincide with that held in other countries; according to Bernard, Grey Blight in Java is only serious when it attacks plants already weakened by faulty conditions of cultivation or by other parasites.

Speschnew has recorded that Grey Blight appeared on tea in the Caucasus in 1898, but whether it causes much damage there is not stated. It occurs on tea in Formosa, where it is regarded as a serious disease.

Brown Blight

(*Colletotrichum Camelliae* Massee)

Brown Blight was first discovered in Ceylon in 1899. Specimens of the diseased leaves were forwarded to Kew and examined there by Massee, who described the fungus as *Colletotrichum Camelliae.* The disease was said to resemble Grey Blight, but to be characterised by the chocolate-brown colour of the fully developed spots.

The spots of Brown Blight are at first yellowish green and somewhat diffuse. As they increase in size they become red-brown or dark brown, with a yellow-green margin. They are usually not zoned, but may be mottled blackish here and there (Plate I., Fig. 2). When old, the upper surface becomes grey as in Grey Blight, and this change often occurs irregularly over the diseased area, so that the spot in an intermediate stage is a mixture of irregular patches of grey and red-brown. The fructifications occur as minute black points scattered over the spot, often with a tendency to group themselves along the veins. Brown Blight spots frequently spread inwards from the margin of the leaf, and form a semi-oval patch extending along the whole of one side and across the leaf to the midrib. In the original description, the diseased area was said to fall out on shaking, leaving a hole in the leaf. This does not seem to be of general occurrence, but Brown Blight spots do appear to break up more readily than those of Grey Blight. Ragged broken patches, extending from the margin of the leaf, and consisting of pieces of dead leaf tissue attached to the veins, are usually attributable to Brown Blight.

As in the case of Grey Blight, Brown Blight can attack the young leaf, and it frequently causes considerable damage on bushes which are just coming into bearing, a few months after pruning. The effect is similar to that of Grey Blight. A large area of the leaf, sometimes the whole leaf, turns blackish brown or black, and in wet weather is soft and rotten. The diseased area may extend down from the tip of the leaf, or in a large patch from one side, or along the margin all round the leaf. The diseased leaves which manage to complete their expansion are usually curled and distorted, with thin, black, broken areas where the tissue has been

killed by the fungus. A spell of wet weather during the dry season appears to produce conditions highly favourable to this phase of the disease.

The fructifications of the fungus (Fig. 6) appear as minute black points scattered over both surfaces of the leaf. These are really minute cavities, the spores being produced beneath the epidermis, which splits when they are ripe. In wet weather these extrude a small heap of spores, which is usually pinkish, but may be brown if the leaf is very wet and rotten, or almost white if approaching dryness. When examined microscopically the spores are found to be hyaline and cylindric without cross walls (Fig. 3). Mixed with the spores are numerous erect, black hairs (setae). The spores are soon washed away by the rain or dispersed in other ways, but the disease can always be identified by the black setae which persist in the cavities in the leaf in which the spores were produced.

Fig. 13.—The effect of Brown Blight. $\times \frac{1}{2}$.

Brown Blight is known to occur in Java, and in Northern and Southern India. In Northern India it is said to be a disease of weak bushes, and it has also been stated that Brown Blight, Grey Blight, Red Rust, and Die-back may be directly traced to deficiencies in the soil. Current opinion in Ceylon classes Brown Blight with Grey Blight; but while it may be negligible when it occurs on the older leaves only, it attacks the young leaf more frequently than does Grey Blight, and is for that reason worthy of more serious consideration.

Under the name of "Marginal Corrosion," a leaf disease

PLATE I.

LEAF DISEASES

FIG.

1. Grey Blight (*Pestalozzia Theae*).
2. Brown Blight (*Colletotrichum Camelliae*).
3. *Cercosporella Theae*, early stage, on leaf just fully expanded.
4. *Cercosporella Theae*, mature spots on leaf just fully expanded.
5. *Cercosporella Theae*, irregular patches on old leaf.
6. *Phoma theicola*.
7. Scabbed leaf, early stage.
8. Scabbed leaf, fully developed stage.
9. Early stage of Black Rot on a young leaf.
10. Bird's-eye Spot (*Cercospora Theae*).

Fig. 10, natural size; the remainder $\times \frac{2}{3}$.

LEAF DISEASES.

has been described from Assam which is said to be caused by a combination of the fungi of Grey and Brown Blights, *i.e.* by the *Pestalozzia* and *Colletotrichum* attacking the leaf at the same time. The leaf begins to shrivel round the edges, and the shrivelling increases until the whole leaf decays: the decayed portion is deep chocolate-brown in colour and quite brittle. It is said to spread faster than either Grey or Brown Blight. The description given would apply quite well to Brown Blight alone, and the occurrence of the two fungi on the same diseased area cannot be taken to indicate that the two are working in conjunction from the beginning of the attack on the leaf. The tea *Pestalozzia* flourishes as a saprophyte on all dead tissues of the tea bush, and it is most probable that in this case it merely follows the Brown Blight. In Ceylon it is not uncommon to find *Pestalozzia* on Brown Blight spots.

Brown Blight can attack the green twigs of the tea bush, generally on bushes which are more or less unthrifty. The affected twigs harden up and become grey. In some cases the leaves become mottled, and the twigs are stunted and begin to flower.

A more serious attack of Brown Blight on the stems has been recorded by Tunstall from Northern India under the name of Die-back (*Gloeosporium* sp.). The young green shoots die back and the leaves fall off. As a rule, light brown patches are found on the leaf. The fungus gains an entrance into the shoots through the wounds made by the pluckers and spreads downwards within the shoots into the woody part of the stem. Spores are produced in abundance on the shoots even before they are dead. It is recommended that in dealing with this Die-back all dead and discoloured wood should be pruned off, and the diseased prunings burnt. The bushes should be sprayed immediately afterwards with Bordeaux mixture to prevent the germination of the spores of the fungus on the fresh pruning cuts, and the spraying should be repeated ten days later. This Die-back is said to be directly traceable to deficiencies in the soil.

Copper Blight

(*Guignardia Camelliae* (Cooke) Butler)

This disease was first recorded on tea in Johore, and it has since been found to be fairly common in India, Ceylon, and Java. The leaf spot caused by the fungus is scarcely distinguishable from Brown Blight, and the available evidence indicates that *Guignardia Camelliae* is the perithecial stage of *Colletotrichum Camelliae*, the fungus which causes Brown Blight.

The spot is usually large and irregular, often extending from the margin of the leaf. On the upper surface it is dark brown, usually mottled with yellow-brown or grey-brown, without any zoning. It becomes grey when old, and then resembles Grey Blight. On the under surface it is greyish brown, sometimes obscurely zoned, and when examined with a lens often appears to be covered with fungus threads radiating from the centre. Microscopic examination, however, shows that these apparent fungus threads are slight ridges in the epidermis of the leaf. They are most clearly evident towards the margin of the spot. The diseased area bears minute black points, which are the fructifications (perithecia) of the *Guignardia*, and also numerous minute brown cavities, arranged more or less in concentric circles. When magnified, it is seen that these cavities are places where the epidermis has fallen out, exposing the dead, brown, inner tissues of the leaf; and on tracing the development of these cavities it is found that they are the sites of minute fructifications (acervuli) of *Colletotrichum Camelliae*, from which the conidia have disappeared.

In Ceylon, *Guignardia Camelliae* usually occurs on the older leaves and is generally passed over as Brown Blight. Raciborski stated that it did not cause serious damage in Java, but Bernard, who has studied this disease in that country, says that a large number of leaves on a bush are often totally destroyed, and the plant may be so weakened that it is readily attacked by other parasites.

The description of this disease, as it occurs in Northern India, differs in several particulars from that given above.

According to Shaw, the first symptom is the appearance of a small, copper-coloured spot on the upper surface of the leaf, irregular in shape, and with a not very clearly defined margin. In the later stages the discoloration extends through the leaf. The upper surface then becomes greyish, with a well-defined margin, and the lower surface is yellow-brown. The diseased patch is covered with minute crater-like spots, which are areas in which the epidermis has disintegrated, leaving small cavities, and, in the older stages of the disease, the fructifications of the *Guignardia* occur as minute black points. The spot is very brittle, and is often traversed by numerous cracks.

Copper Blight has also been described by Tunstall, who states that it is most in evidence about the time the second flush of leaf makes its appearance. At that time, especially on the large-leaved varieties of tea, numbers of leaves may be noted, bending over in a peculiar manner. These leaves exhibit a pink or coppery sheen on the under surface. The leaf subsequently straightens out, and bright brown patches appear. In a later stage, the patches turn grey and are covered with minute black dots, thus resembling Grey Blight. Tunstall states that Copper Blight differs from Brown Blight in the colour of the spot, the former being brighter.

The disease is said to spread rapidly, but to attack merely the older leaves. The following method of dealing with it has been recommended by Tunstall for Northern India.

On the first appearance of the disease all the affected leaves should be removed and burnt. The bushes should then be sprayed with Bordeaux mixture, and it is desirable that the spraying should be repeated a fortnight later. In the cold weather, after the bushes have been pruned, all the spotted leaves should be removed and burnt, and the bushes sprayed with soda solution before the new shoots appear. After the first flush appears, they should be sprayed with Bordeaux mixture, and if the disease continues serious they should be sprayed again after the first flush has been removed.

Bird's-eye Spot

(*Cercospora Theae* Breda de Haan)

This leaf disease is quite common, but the spots caused by it are small and do not attract attention. It occurs usually on the older leaves and does very little damage, but it has been known on a few occasions to attack the flush. Originally described from Java, it is now known to occur in Ceylon, and has been recently recorded from India.

The spots (Plate I., Fig. 10) are circular, at first purple-red, with an indefinite yellow-green border. The centre becomes sunken below the surface of the leaf. When fully developed, they are white, surrounded by a narrow purple-red ring. In general the spots are regularly circular and not more than 2 or 3 millimetres in diameter.

The fructifications appear as minute black points in the centre of the spot. Each of these points is a cluster of erect stalks (conidiophores) which bear long, extremely thin spores (conidia) (Fig. 3).

In India the centre of the spot often falls out, leaving a clean-cut circular hole.

Cercosporella theae Petch

This disease was first observed in Ceylon in 1909. It occurred then on plants in a nursery about eight months old, especially in beds which had not been shaded. The plants which were attacked shed all their leaves. Recently it has occurred on several up-country estates on old tea and has caused considerable damage. Its appearance is largely governed by weather conditions; it usually appears during the monsoon rains, and stops when the rains cease.

The effect on the tea leaf is very variable, the appearance of the diseased leaves varying according to the age of the leaf. On the young leaf (flush) it causes minute, more or less circular, sodden-looking black or black-brown spots (Fig. 14). These may occur in large numbers on a single leaf, and the leaf in its subsequent development becomes distorted and crumpled; but if the rains continue they may run into one another so that the whole leaf becomes black and rotten. On older leaves it causes circular spots like

those of the Bird's-eye Spot, but generally larger. These latter spots may be up to 5 millimetres in diameter, and several may occur on the same leaf; they are at first black, then grey or greyish white, with a well-defined purple or purple-black, slightly raised marginal line (Plate I., Figs. 3, 4).

On the old full-grown leaves the fungus usually causes large diffuse patches. These are at first greenish brown, becoming chocolate-brown mottled with yellow-brown, and somewhat resembling Brown Blight (Plate I., Fig. 5). These spots extend indefinitely and may cover the whole leaf, but if their growth is arrested they become grey, with a well-defined, narrow, purple-black margin, up to a millimetre wide. The lower surface of these spots is dark brown and somewhat sodden-looking, becoming grey-brown, with a translucent green margin, when old.

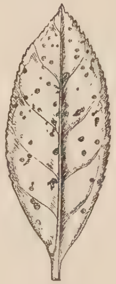

Fig. 14.—*Cercosporella Theae*; spots on young leaf, natural size.

Bushes attacked by this disease frequently lose most of their leaves, and the upper branches may be completely defoliated. The remaining leaves bear circular grey spots or large discoloured patches. The fungus may also attack the green stem, on which it causes purple sunken areas.

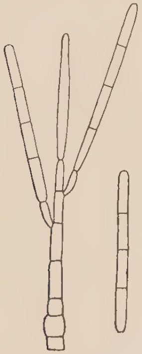

Fig. 15.—Conidiophore and conidia of *Cercosporella Theae*. ×300.

On examining the lower surface of the spots with a lens, a fine, white, cobwebby mycelium may be detected, spreading over the diseased patch, and from the patch over the surrounding green part of the leaf. This is best seen on the larger patches. The mycelium is never very abundant, and it may be absent from the smaller spots. Apparently it does not become superficial until the spots have attained a certain size, though, as will be evident later, it may be superficial from the beginning. The spores (conidia) are produced on this external mycelium, either directly or on branched conidiophores, and as they are comparatively large (up to 130 μ), they can in many cases be detected with

a simple lens in white clusters on the lower surface of the spot. As the spores are borne externally they can easily be distributed by the wind.

In practically all the recent outbreaks of this disease on tea, the affected bushes have been situated near Acacias, and it has been determined that the disease first attacks the Acacias and then spreads from them to the tea. In general, the disease has occurred on tea interplanted with *Acacia decurrens*, but it will also attack *Acacia dealbata* and *Acacia melanoxylon*. When *Acacia decurrens* is attacked, the trees are defoliated, the leaflets and the leaf-stalk, or rachis, falling separately. The smaller branches may die back, and young plants may be killed, but, in general, the trees put out new foliage when drier weather supervenes.

The disease is conveyed from the Acacias to the tea, either by means of its spores which are blown by the wind, or washed by the rain, on to the surrounding bushes, or by the falling leaflets of the Acacia. As the leaflets are small and flat, they adhere, when moist, to the leaves of the tea bush long enough to enable the fungus to grow from them to the tea leaf. It is easy to find in an affected field numerous instances in which an Acacia leaflet is attached to a tea leaf by a weft of mycelium in the middle of a diseased patch, and others in which a spot is beginning to form from a similarly attached leaflet. In general, it would appear that the smaller circular spots are the result of an infection by spores, while the larger patches are due to the transference of the fungus by means of the falling Acacia leaflets, but that is not universally the case. Naturally, when the disease is transferred by a leaflet, the mycelium is superficial on the tea leaf from the beginning of formation of the spot.

Cercosporella Theae has also been found to attack Red Gums (*Eucalyptus robusta*), and Karri (*Eucalyptus diversicolor*). In the cases hitherto recorded, the Eucalyptus had been interplanted with Acacia, either in forest plantations or in firewood reserves. The spots on the Red Gum leaf are usually large, and may be circular or may extend irregularly from the leaf margin. They are grey-brown, or grey bordered by a brown zone, with a thin white layer of mycelium spreading from the spot on the under surface. The leaf of the Red Gum appears to withstand the attack of the fungus

better than the tea leaf, and no defoliation has been observed in the case of that plant. Up to the present, the fungus has not been recorded on Red Gums planted alone or in tea, nor has it been known to spread from Red Gums to tea.

Acacia decurrens has proved of great value in up-country districts of Ceylon for wind-belts and green manuring, and it would be unwise to condemn it altogether because of the occurrence on it of a leaf disease which also attacks tea. Whether it is advisable to cut out the Acacias where this disease occurs must depend upon the circumstances of the individual case. The point to be decided is whether the benefit derived from the Acacias compensates for the damage to the tea.

Rim Blight

(*Cladosporium* sp.)

Species of *Cladosporium* are commonly found on decaying vegetable matter, and under certain conditions they can become parasitic. One has been recorded as parasitic on tea in Assam, and has been found to occur in Ceylon. In Assam, the disease caused by *Cladosporium* is known as Rim Blight. It generally attacks young leaves of the better jats of tea.

The fungus attacks the leaves at the serrations on their edges. As it spreads inwards the affected parts turn pale yellow, and then brown, the brown patch appearing thinner than the healthy portions of the leaf. If the leaf dries, the diseased part round the margin shrivels up. When the brown stage has been reached, the fructification appears in the form of dense tufts of dark green, or olive-green, stalks (conidiophores) on which the spores are produced. As the spores are superficial, *i.e.* borne on the outside of the leaf, they are readily distributed by the wind.

In Assam the worst Rim Blight in 1916 occurred on severely pruned tea, and it was suggested that the pruning helped to make the plant more susceptible. The worst case seen in Ceylon occurred in pruned tea which was suffering from the root disease caused by *Botryodiplodia*. In this case the leaves turned yellow between the veins, yellow irregular patches being formed, or the yellow patches spread inwards from the margin of the leaf. The patches then turned brown

or blackish brown, and in the majority of cases the leaves, in the oldest stage, consisted of a green area bordered by a thin, shrivelled black patch. Sometimes the diseased part was marginal and extended round the leaf ; in other instances half the leaf was black and shrivelled while the other half was green and healthy. This result is very similar to that of Grey Blight and Brown Blight on the flush, but the preliminary yellowing distinguishes it from these diseases. The tufts of conidiophores often arise on the teeth along the leaf margin.

Rim Blight is not common in Ceylon, and it would appear only to attack bushes which are more or less weakened or unhealthy.

Japanese Exobasidium Blight

(*Exobasidium reticulatum* Ito and Sawada)

A leaf disease, caused by a species of *Exobasidium* different from that of the Indian Blister Blight, has been recorded from Honshu and Formosa. It is common in the tea districts of Northern Formosa, and one of the most serious diseases of tea in Province Suruga, Honshu. It appears early in the season, and in some districts causes a loss on the first plucking estimated at about 20 per cent. It is said to cause almost as much damage as Blister Blight. Some plantations are so seriously affected that scarcely any young leaf is free from disease spots.

The first indication of the disease is a small pale yellow spot, and if the leaf is held up to the light a network of dark lines is seen within the tissue of the spot. The spot is indefinite and irregular in outline, and gradually enlarges until it attains a diameter of 2 or 3 centimetres, or sometimes until it covers the whole leaf. The colour of the upper surface meanwhile changes to brown, and finally to dark brown. On the under surface of the leaf the spot at first takes on a grey, dusty appearance, but, as it matures, the network of dark lines becomes slightly elevated above the rest of the surface. The epidermis then splits along these lines and exposes the fructification of the fungus as a white network, on which the spores are produced. As it ages, the netted fructification (hymenium) turns dark brown

from the centre outwards, while the affected area dries and shrinks.

The disease differs from Blister Blight in the colour and shape of the spot, which is never blistered, and in the reticulated hymenium.

Sooty Mould

(*Meliola*, etc.)

Under certain circumstances the leaves and twigs of tea become covered with a black film, usually with a more or less powdery appearance. This may occur over the greater part of a bush, or a number of bushes in a continuous patch may be affected. The black covering is generally known as Sooty Mould, Soot Blight, or Black Blight, and consists of a thin layer of mycelium bearing fructifications of several kinds. The black layer in most cases is easily detached from the leaf, and it often splits away in flakes if a leaf is gathered and allowed to dry. It is practically entirely superficial, though it may have minute suckers which penetrate the epidermis and serve to attach the fungus more firmly to the leaf. In the case of tea the fungus, as a rule, is not parasitic on the bush. In general it does not live at the expense of the tissues of the leaf, but on the secretions of insects which it finds on the surface. It does no direct injury to the bush, but it may perhaps have an indirect effect by shading the leaf and thereby interfering with the manufacture of plant food.

To get rid of Sooty Mould, which is dependent upon the presence of insects, the bushes must be sprayed with an insecticide, such as kerosene emulsion, which will kill the insects, the particular spray fluid to be employed depending upon the kind of insect present. In some instances, it has been found that the insects were not living on the tea bush, but on an overhanging tree, from which their secretions fell on the tea beneath. In such a case the tree should be lopped or sprayed.

The fungi which constitute Sooty Mould are species of *Meliola*, *Capnodium*, etc., the particular species no doubt varying with the locality. Sydow and Butler have described two species of fungi on tea, which fall under this head, viz.

Limacinula Theae, found on tea in Darjeeling, and *Asterina Camelliae* on tea in Assam; and Sawada has recorded from Formosa, *Zukalia nantoensis*, *Scorias capitata*, and *Zukalia Theae*, fungi of similar appearance on leaves and twigs of the tea bush.

Phoma theicola Petch

A leaf disease of tea, differing in several respects from the common Grey and Brown Blights, was noted in Ceylon for the first time in 1915. It attacked young plants in the nursery, and was fairly prevalent in certain districts. It has since been found on full-grown bushes, generally on the upper leaves.

The spots (Plate I., Fig. 6), as a rule, appear between the lateral veins, usually several on either side of the mid rib. At first they are roughly circular, but as they increase in size they extend outwards towards the margin and become oblong, oval, or angular. They are generally uniformly bright red-brown in colour, sometimes almost red. Ultimately they may coalesce, almost the whole leaf, or one side of it, becoming red-brown. The fructifications occur scattered over both sides of the spots as minute, slightly elevated points. On old bushes, the spots may not be limited by the veins, but spread from the tip or from the margin, and the surrounding area of the leaf is frequently yellow or yellow-brown.

Phaeosphaerella Theae Petch

The characteristic feature of this disease is the formation of numerous irregular holes, usually small, in the leaf (Fig. 16). It occurs in Ceylon, but has been observed only on a few occasions. In one instance, where it occurred on tea six months after pruning, it attacked the older leaves on the recently plucked shoots. It has not been known to cause any serious damage.

The leaves become covered with small yellow spots, at first somewhat circular, but afterwards becoming angular, and frequently extending in narrow prolongations from the corners. The centre of the spot turns grey or grey-brown, dries, and falls out, leaving an irregular hole, bordered by a narrow brown zone of dead tissue. The holes are usually

small, up to a diameter of about 5 millimetres, but they may run into one another and form a ragged hole extending nearly the whole length of the leaf. In many cases the spot takes the form of a line, so that when the dead tissue dries, a mere slit is produced. Sometimes these slits are forked or branched.


FIG. 16.—Effect of *Phaeosphaerella Theae*, natural size.

The fructifications of the fungus are produced as minute black points in the dead brown tissue at the margin of the wound.

It may be noted that when tea is interplanted with rubber, or with dadaps, the falling leaf-stalks of the trees may pierce the tea leaves, and produce narrow wounds which have an appearance similar to those of this disease.

SCABBED LEAVES

This disease is common in Ceylon, more especially on the older leaves of the bush. Apparently it does not attack the flush, but it may begin on leaves which are just full-grown, though it does not attract much attention until the leaves are old and the characteristic appearance is well developed.

The affected leaves at first bear yellowish-green spots, which become blackish brown, and then black. These spots are angular or irregular, or have a lobed, cloud-like margin. A single spot, in the early stages, may exhibit all the three colours and appear mottled. They are usually numerous, and vary considerably in size ; ultimately they may coalesce and cover the whole leaf (Plate I., Fig. 7).

At first the spots appear merely as a discoloration of the leaf. As they grow older they become elevated above the surrounding parts of the leaf, and the leaves bulge

upward between the veins and become brittle. The blackened areas crack, and the cracks turn grey. In some cases the whole of the blackened spot turns grey, while in others the same grey coloration extends over the surface of the leaf round and between the spots. In the latter case, however, the discoloration of the part of the leaf which was not blackened is often due to the secondary attack of Grey Blight, or *Guignardia*. The final result is usually a large, irregular spot, extending over a great part of the leaf, intermingled black and grey, and irregularly blistered and cracked (Plate I., Fig. 8).

The black colour does not, as a rule, extend to the lower surface of the leaf. In advanced stages, the under surface may bear minute, watery-green, translucent dots, and sometimes a few black points.

Sections through the affected leaves show that the elevation of the blackened areas is due to a division of the palisade cells and an exceptionally strong thickening of the cell walls at the upper ends of the same cells. The brittleness of the affected leaves is also due to this development. To some extent this cell division is normal; it takes place in old leaves of tea, and for that reason the older leaves are brittle. But in these "scabbed" leaves it occurs prematurely in the blackened areas, while the unaffected parts of the leaves are still in the younger condition, and the thickening of the cell walls is much more strongly developed than in normal leaves. In the young stages the cells of the blackened areas have purple contents, but when old the cell contents are brown.

The cause of this disease is not known. No fungus has yet been found in the diseased spots. In some respects the spots resemble those caused by *Discosia Theae*, as figured by Speschnew, but no such fungus occurs on these spots in Ceylon. Up to the present it has not caused serious damage.

Leaf Disease in Nurseries

The leaf diseases which occur in tea nurseries are, in general, those which attack the mature plant. Grey Blight and Brown Blight are frequent, especially if the plants are stunted, or badly nourished, or grown on poor soil. *Cerco-*

sporella Theae has been found on nursery plants, and *Phoma theicola* is sometimes quite common. In dealing with leaf diseases in the nursery, collecting and burning the diseased leaves is usually practicable, but in the case of general attacks, spraying with Bordeaux mixture should be adopted.

The following leaf diseases have been recorded from the countries named, but few details are as yet available concerning their effect.

Hendersonia theicola Cooke

This fungus was described by Cooke in 1872 from diseased tea leaves sent from Cachar. He stated that it caused serious injury to the leaf, but did not describe the appearance of the affected leaves. It does not appear to have been recorded again from India, but Speschnew has recorded it as occurring in the tea plantations of the Caucasus. Speschnew refers to it as a very dangerous fungus, but as he states that it has not caused serious damage in the Caucasus, he was probably repeating Cooke's version. What appears to be the same fungus has been observed in Ceylon, but always in conjunction with other diseases, so that it is not possible to describe the leaf spot caused by it alone, or to state what damage is due to it. Speschnew records that it frequently occurs on the same spots as Grey Blight.

According to Speschnew, the spots caused by *Hendersonia* resemble those of Grey Blight, but are usually smaller and browner. The black fructifications (pycnidia) are smaller than those of Grey Blight, and open by a regular pore through which the spores are extruded. The spores are cylindric, three-septate, pale brown, with the terminal cells sometimes paler.

Gloeosporium Theae-sinensis Miyake

This leaf disease was recorded in 1907 from Japan, where it was widely distributed in the neighbourhood of Tokyo. The affected leaves bear large spots which are at first red-brown, but ultimately, as is usual in tea leaf diseases, become grey. The spots spread from the margin and frequently extend over the whole leaf. The fructifications

are minute and black, and occur scattered over the upper surface of the spot. Further details of this disease are lacking.

Septoria Theae Cav.

This fungus was originally discovered on the leaves of tea cultivated in the Botanic Garden at Pavia. It is stated by Speschnew to occur in the Caucasus, but the description he gives is that of *Discosia Theae*.

Discosia Theae Cav.

This is another fungus which first appeared on tea in the Botanic Garden at Pavia, and has since been discovered in the tea plantations of the Caucasus. It causes, on the upper surface of the leaf, circular, definite, black spots of varying size, which are often confluent. The black spots are formed beneath the cuticle, which is elevated in the centre of the spot and ultimately splits. Although the leaf tissue between the spots is generally sound and green, yet the spots often are present in such numbers that more than half the leaf surface is affected. Speschnew states that it is always to be found in the Caucasian plantations and must be regarded as a serious parasite. It is not known elsewhere.

Phyllosticta Theae Speschnew

This fungus causes more or less circular greyish-white spots on the upper surface of the leaf. The spots vary from one to six millimetres in diameter, and have no definite margin. The fructifications occur as minute raised points scattered over the spots.

The disease was discovered by Speschnew in the Caucasus. He states that the leaves may be so closely covered with the spots that the whole crop is threatened. Spraying the bushes once or twice with weak Bordeaux mixture (not exceeding 1 per cent) has given good results.

Macrophoma Theae Speschnew

This leaf parasite occurs chiefly on the under side of the tea leaf, where it causes irregularly circular greyish-brown

spots. The minute black fructifications are formed beneath the epidermis of the leaf, which splits when they are ripe. It has been found only in the tea plantations of the Caucasus, and apparently no serious damage has been caused by it.

Macrosporium commune Rabh. var. *theicolum* Spesch. and *Pleospora Theae* Spesch.

According to Speschnew, these two fungi occur on the same leaves, and are different stages of the same species. They attack chiefly the lower leaves of the tea bush, late in the year.

The leaves attacked by the *Macrosporium*, the conidial stage, have much the same appearance as leaves attacked by Sooty Mould, but while the Sooty Mould is superficial and its patches can be scraped or peeled off, the *Macrosporium* tissue is firmly attached. The fungus causes large irregular spots, on the surface of which appear minute, raised, dark olive or black cushions. When magnified these cushions are seen to be groups of erect stalks, on which the conidia are produced. The fungus thus resembles in its general habit the *Cladosporium* found on the leaves of tea in Ceylon and elsewhere, but it differs from the latter in its spores (conidia), which are divided by cross walls transversely and longitudinally. The *Pleospora* form appears subsequently, and produces spores which enable the fungus to survive the winter.

This disease has hitherto been found only in the Caucasus. As it attacks the leaves late in the year, and the bushes are pruned in the winter, it is not considered dangerous. In the case of bad attacks, spraying with Bordeaux mixture after the pruning is recommended.

Venturia Speschnewii Sacc.

This is another leaf parasite recorded from the Caucasian tea plantations. It causes broad, brownish, indistinct spots on the upper surface of the leaf. The corresponding areas on the lower surface are light grey, passing without definite margin into the surrounding green of the leaf. The fructifications appear on the upper surface as pale, roundish points, at first covered by the cuticle of the leaf, but subsequently

projecting through it as small hemispherical bodies which are covered with minute hairs.

No details of any damage by this fungus are on record.

Chaetophoma Penzigi Sacc.

This fungus was originally discovered by Penzig on orange leaves in Italy. Speschnew states that it occurs in the Caucasus on leaves of tea, in company with *Septoria Theae* (see p. 46), and it is consequently uncertain which fungus causes the leaf spot in question. Spots on which the *Chaetophoma* only occurs are much smaller than those on which the two fungi are found together. The disease caused by this fungus (or the two) can be arrested by spraying twice with Bordeaux mixture, if taken in time.

Leaf Abnormalities

Chlorosis

Variegated leaves, green and yellow, or green and white, are often found on the tea bush. In the commonest case, one half of the leaf is green and the other yellow. Sometimes only a single leaf is affected, but more usually all the leaves on a twig are variegated. As a rule, the effect is confined to a single twig. This phenomenon is known as chlorosis.

The leaves of the tea bush may become variegated as a secondary effect when the bush is attacked by Red Rust, or in the early stages of the root disease caused by *Botryodiplodia*. In such cases the yellow patches are diffuse and merge gradually into the green, while in cases of chlorosis of tea which are not due to fungus or algal disease, the two colours are usually sharply defined. As stated above, the latter type of chlorosis usually affects only one branch ; if the whole bush bears green and yellow leaves it is probably attacked by some disease.

No adequate explanation of the phenomenon of chlorosis has yet been put forward. The white or pale yellow colour is due, as a rule, to a lack of chlorophyll in those parts of the leaf, but it is not known why this should occur. There

are two types of chlorosis in general, other than that which is associated with fungus disease. One of these is contagious, although no parasitic organism has been detected in the chlorotic leaf; this type is the cause of the white leaf in the widely cultivated Caladiums, Abutilons, etc. But the commoner chlorosis of cultivated plants is not contagious, and that of tea belongs to the latter type. It is claimed that chlorosis is especially prevalent on calcareous soils: and conversely it is known that the common variegated garden plants cannot be grown on some soils, any planted in them becoming green. Watering variegated plants with a solution of iron sulphate is said to convert the plant to the normal colour.

Double Leaves

Abnormally shaped leaves are occasionally met with on the tea bush. Perhaps the commonest form is that of the twin leaf, in which two leaves appear to be fused together by their edges for part of their length. This sometimes occurs in conjunction with fasciated stems. In some instances there are two distinct mid-ribs from the base of the leaf; in others the mid-rib divides into two at varying distances from the leaf-stalk. In these cases the two leaves lie in the same plane.

As a variant of the above, a fully formed leaf may arise from the mid-rib of another leaf. This may be regarded as a branching of the mid-rib in a plane perpendicular to the leaf.

In some instances the mid-rib may divide into two branches which unite again at the apex of the leaf, without any separation of the leaf blade into two parts.

There is no reason to attribute any of these phenomena to insect or fungus agency.

Dwarf Leaves

Tea bushes sometimes produce large numbers of very small leaves instead of, or in addition to, the leaves of normal size. These leaves are often produced on short shoots which arise as secondary branches on the young wood.

They are usually long relatively to their breadth ; some attain a length of four centimetres and a breadth of one centimetre, while others may be two centimetres long and

FIG. 17.—Shoots bearing dwarf leaves, arising from a branch with normal leaves, natural size.

only a millimetre broad. The affected shoots branch repeatedly, so that the small leaves are ultimately grouped in dense clusters.

This effect has not been traced to any disease.

CHAPTER III

LEAF AND STEM DISEASES

Blister Blight

(*Exobasidium vexans* Massee)

This disease, which was referred to by Dr. Watt as "one of the very worst blights on tea," has been definitely known to exist in Assam since 1868, and is reported to have occurred there ten years previously. In 1895 Watt sent specimens to Kew, where it was examined by Massee, who described the fungus which causes it as *Exobasidium vexans*. It was apparently confined to Assam until 1908, when severe attacks broke out in the Darjeeling district. As far as the records show, it is still only known in Upper Assam and Darjeeling. It has not been recorded from Southern India, nor from Ceylon or Java.

The first indication of a blister is a small, pale green, pale yellow, or pinkish, translucent spot which is easily seen against the darker green of the rest of the leaf when it is held up to the light. In some cases the spot is deep red on both sides, the colour of red ink, and the red tinge persists even when the spores are ripe. The circular spot enlarges until it reaches a diameter of a quarter to half an inch. On the upper side of the leaf the spot gradually becomes depressed into a shallow cavity, while on the under side it becomes correspondingly convex, and thus forms the blister from which the blight takes its name (Fig. 18). The upper concave surface of the spot is smooth and shining, and the colour is usually a paler green than the rest of the leaf. The lower convex surface, on the other hand, is dull, and at first grey as if dusted with a white powder, but when mature it becomes pure white. This white appearance is due to the

outgrowth of a dense velvety pile of fungus filaments, on which the spores are produced. In some cases, some filaments and spores may be produced on the concave upper surface; and in others the form of blister may be reversed, the upper side of the leaf being convex and the lower concave. Both these forms of the blister may be found on the same leaf, but the spore-bearing surface is always chiefly on the under side.

FIG. 18.—Blister Blight on a tea leaf, natural size.

After the leaves of a bush have been attacked, the disease spreads to the leaf-stalks and the young green stems. It is not as conspicuous on the stems as on the leaves, but the damage is more serious as the stems are killed above the point of attack. No blisters are formed on the stem, but a spot is produced similar in colour to that on the leaf, though it is never deep red. The spot elongates and also gradually encircles the stem, which becomes slightly swollen at this point. When the spores are ripe the spot turns grey, but it does not become pure white like the blister on the leaf. The fungus penetrates through the stem, and consequently the leaves and buds above the diseased part wither and blacken. Finally the stem bends over and breaks off at the affected spot. When a bush bears numerous diseased twigs it presents a black, unsightly appearance.

Leaves often become folded or irregularly rolled up owing to the development of a blister on the mid-rib, while if several blisters occur near the margin the leaf often becomes curled and distorted. Up to twenty blisters may occur on a single leaf, and they may remain distinct, or several may

coalesce to form a large patch with an irregular outline. In some cases the whole under surface of the leaf may be covered with an even mass of blisters.

The disease is propagated by wind-blown spores, though on estates already infected it is possible that the spores may be conveyed from bush to bush on the clothing of the coolies. The spores, if kept moist, germinate within five and a half hours, and if they happen to have alighted on the lower surface of a tea leaf, the germ tube enters through a stoma and ramifies between the cells of the plant. A mass of mycelium is ultimately formed beneath the lower epidermis of the leaf, and, from this, groups of filaments emerge through a stoma or through the ruptured epidermis, forming the close, woolly covering of the blister. Some of these filaments bear spores, while others are barren. Those that bear spores are of two kinds; the one kind bear two-celled spores (conidia), the others bear one-celled spores in pairs (basidiospores).

From the time of infection to the appearance of the translucent spot about eleven days elapse, while the blister is fully formed and producing spores six to eight days later. These times vary according to weather conditions, and it has been stated that the time from inoculation to spore production may be only ten or eleven days. The spores are said to lose their capacity for germination in two to three days. When a leaf is over four weeks old it is past the stage at which it can be infected.

It has been suggested that the mycelium of the fungus persists within the branches of the tea bush during the cold weather, and becomes active again, reproducing the blister stage, when conditions are favourable. It is, however, now established that the fungus does not persist for any appreciable time in the living or dead plant tissues after the spores have fallen. On many tea gardens in Assam the disease dies out of its own accord, only reappearing when spores of the fungus are reintroduced from other gardens. But in the hill districts the weather conditions are more favourable to the fungus, and at any time of the year active blisters may be found on bushes growing in damp, shady places. Thus in these districts there is a continual infection of new leaves or other bushes by spores on a small scale, and in this way the

disease is perpetuated until weather conditions are favourable for the development of an epidemic.

In Darjeeling, the disease is said to appear erratically in a field. It does not appear in one spot and then spread from that centre in a continuous patch, but several bushes here and there are simultaneously badly affected, while scattered bushes are lightly affected. The disease may then become general, and increase until the leaves and shoots are so badly attacked that plucking is stopped. Infection occurs to a notable extent when a spell of wet weather follows a few days' sunshine, and under favourable conditions the disease spreads with terrible rapidity. Shade favours its development, and it is worst in low-lying, damp, shady spots. Some bushes often appear to be resistant to the disease, and remain healthy and free from blisters, although the surrounding bushes are suffering severely.

Mann states that, in Assam, Blister Blight appears about the third week in April to the first week in May, and the tea first affected is almost always unpruned tea, which quickly takes on an alarming appearance only realised by those who have seen it. The blight then spreads to the remainder of the tea, ruining the first flush-stalk and the leaves, and in bad cases making it necessary for the bush, at the end of May, almost entirely to make fresh growth right from the level of the pruning. As a result, this not only very seriously curtails the yield of the season, but also renders the wood which afterwards grows on the bushes permanently weaker than it would otherwise have been. It will at once be seen that the worst effect will naturally be felt on "cut back" tea, where the yield is of less immediate importance than the growth of thoroughly vigorous healthy wood for pruning purposes. The killing down of nearly every fresh green shoot on a heavy pruned bush by Blister Blight during the month of May is one of the most hopeless of sights to be seen on a tea estate.

According to Mann, Hybrid tea is usually the least attacked in Assam, and the higher Assam indigenous types perhaps the most. Between these two extremes the same type seems to differ in susceptibility according to its position and treatment. "Manipuri" in some places was almost immune; in others it seemed almost as much affected as

the best jats of Assam. With regard to the outbreak in the Darjeeling district, McRae states that the blight attacked the high quality Assam and Hybrid jats most severely, while China and Manipuri were not so much affected ; but in some gardens China was badly attacked.

When any new fungus parasite attacks a cultivated plant it is an obvious assumption that the fungus has previously lived on wild plants, possibly related to that under cultivation, and has, more or less suddenly, adopted a new host in the cultivated species. It has been asserted on several occasions that "Blister Blight" has been found to occur on jungle trees and shrubs, but most of the supposed blisters have proved not to be caused by fungi, or if due to fungi, not caused by *Exobasidium*. The species of *Exobasidium* are, as a rule, strictly limited in their range of host plants, and any given species may be expected to occur only on closely related plants. Up to the present no *Exobasidium* on a wild plant has been found to fulfil the condition required to demonstrate its identity with *Exobasidium vexans*, viz. that the spores from the wild plant shall be capable of producing Blister Blight on Tea. The sudden appearance of Blister Blight in Darjeeling is not explainable on the information at present available.

The following treatment has been recommended for Blister Blight :—

1. In the cold weather as much tea as is practicable should be thoroughly cleaned out and sprayed with a solution of 2 lb. caustic soda in 10 gallons of water. Tea which bears much green growth, such as unpruned, and lightly pruned, tea, and seed bearers should be sprayed with Bordeaux mixture.

2. In the rains, if Blister Blight persists or reappears, spray with a solution containing 2 ounces common salt and 2 ounces lime in one gallon of water.

Experiments have been conducted in Darjeeling to determine the relative value of different sprays against Blister Blight. Diseased leaves were gathered from selected blocks, and the bushes then sprayed with lime-sulphur mixture, Burgundy mixture, and Bordeaux mixture, each in several different strengths, the operations of plucking and spraying being repeated four times at weekly intervals. One per cent Burgundy mixture gave the best result.

Red Rust

(*Cephaleuros parasiticus* Karst.)

Red Rust has been reckoned one of the most serious diseases of tea in Northern India. From the literature relating to tea in India it may be deduced that the disease has existed there in a minor degree for many years. It began to attract attention about 1880, when it was termed White Blight, because on shoots attacked by it the leaves sometimes became variegated, or in a few instances quite white. But it was not until 1889 that the cause of the disease was determined by Cunningham from specimens sent from Nowgong (Assam). The serious nature of the disease was then pointed out, but the warning appears to have passed unheeded.

In 1895 Watt travelled through the tea districts of Assam, and found this disease much more prevalent than had been supposed, though he stated that he had no direct evidence that it occurred as a dangerous tea blight in any other locality than Assam. Since then, however, it has been shown to be present in every plains district of North-East India, and is admitted to have an important effect on the health of the tea bush and on the crop.

Mann and Hutchinson refer to it as a blight which, if unrestrained, will inevitably ruin tea properties in almost every tea district of North-East India. They stated, in 1904, that they had found the dangerous stem form of the alga in every district of Assam, without exception. In Cachar, its ravages were as serious as in Assam, and it was very probable that it was one of the most serious causes of the decline and abandonment of many of the old teela gardens. It is the first blight which appears seriously when the bheels of Cachar lose their original fertility and begin to decline in luxuriance. It has been noticed in Sylhet, in the Duars, and in the Terai, and, except the higher parts of the hill gardens, no section is absolutely free.

The name "Red Rust" is an unfortunate misnomer, for the term "rust" is universally employed for the diseases caused by a particular class of fungi, the *Uredineae*, well known for their attacks on cereals. In the present case

the parasite does not belong to that class, and is not even a fungus, but an alga. Algae are known to the majority only as sea-weeds, but there are other kinds which live in fresh water and form submerged green filaments, or the green or red scum on the surface of pools, while yet others grow on damp surfaces and discolour them green or red. In the tropics, wherever the rainfall is sufficiently high, numbers of algae are found living on leaves; the covering of vegetation so often found on jungle leaves consists generally of algae and mosses. The algae connected with Red Rust, *Cephaleuros mycoidea* and *Cephaleuros parasiticus*, belong to these leaf-inhabiting species, and they have the further peculiarity that their cell contents are (chiefly) orange, not green. Another alga of the same class forms the red stain so often seen on coconut stems.

The species of *Cephaleuros* have been the subject of several botanical investigations, and a considerable volume of information has been amassed concerning them. But the particular species which infest tea cannot be said to have been critically examined by any one who has made a special study of algae. Hitherto all the forms of *Cephaleuros* on tea have been assigned to one species, *Cephaleuros mycoidea*, but there are undoubtedly two species which occur commonly on tea, viz. *Cephaleuros mycoidea* and *Cephaleuros parasiticus*, and the latter is the one which causes damage to the leaf.

If any one gathers leaves of jungle trees or shrubs, particularly those which have a hard, polished surface, he will not be long in discovering that many of them bear on their upper surface thin red or white discs (Plate II., Fig. 1). These red discs are, in general, *Cephaleuros mycoidea*. The alga, in the majority of cases, is merely epiphytic, that is, it lives on the leaf, but does not derive any nourishment from it. The cells of the leaf, immediately underneath the alga, may be discoloured and dead, but there is a difference of opinion whether this is due to the penetration of the epidermis by filaments of the alga, or an effect of shading, etc.

The red discs are superficial, *i.e.* they lie on the surface of the leaf, though they are firmly attached. As a rule they attain a diameter up to five millimetres. They have a radial structure, being composed of cells arranged in rows which radiate from a centre. Frequently the margin is

lobed, and in many cases part of the disc may be wanting, so that the alga consists of more or less triangular sectors, united at their apices (Plate II., Fig. 2). At first the disc is smooth, but as it grows older it produces a number of erect, red hairs which are easily distinguishable if the leaf is held up to the light and looked at edgeways. The hairs are of two kinds: the one kind bear a number of spore-like bodies, sporangia, at the apex, while the others are barren and pointed. The sporangia are easily detached, and may be blown by the wind or washed by the rain to other leaves or plants. There they open, and liberate a number of minute zoospores, each of which can give rise to a new disc, or alga plant. The red discs are often attacked by a fungus, and they then turn white,—hence the occurrence of red and white discs on the same leaf. The leaves of tea, as well as a host of other plants, may bear *Cephaleuros mycoidea*, without showing any appreciable injury.

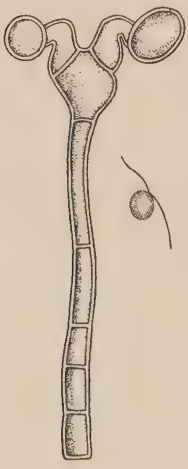

Fig. 19.—Sporangiophore of *Cephaleuros*, ×300; and a zoospore, ×500.

A second species, *Cephaleuros parasiticus*, frequently occurs on the leaves of tea, and is undoubtedly parasitic (Plate II., Fig. 3). It has been found common in Ceylon in cases where the stem form, which will be described later, has caused serious damage. The first appearance of this form is a small, translucent, watery-looking, green spot on the leaf. In Java, such spots have been styled "oil spots." They are not always due to *Cephaleuros*. On the upper surface the spot becomes purple-red, then black, with a purple margin which is sometimes swollen. On the under surface it is purple-red, becoming grey-brown when old, with either a purple, or a dark, watery-green, margin. The alga during the formation of the spot lives entirely within the leaf, and in some cases it elevates the epidermis in a pattern similar to the disc of *Cephaleuros mycoidea*. When it is mature, it produces hairs, like those of the superficial discs, but usually more yellow, which push out through the epidermis

and cover both the upper and under side of the spot. Here again the actual damage caused by this attack on the leaf is not very serious. The spots are, as a rule, small, though in some cases long, oval, black or scaly patches, covered with erect orange hairs, may be formed along the mid-rib, sometimes nearly the whole length of the leaf. If, however, the alga attacks the leaf stalk at its junction with the stem, the leaf soon falls. The occurrence of the spots on the leaf blade is often followed by an attack on the leaf stalk, due to infection in that position by spores washed down by the rain from the fruiting patches above.

In the same way the spores may be washed down, or blown by the wind, on to the green twigs. On the twigs spots may be produced, at first watery green, then black and covered with clusters of orange hairs, exactly similar to the spots caused by *Cephaleuros parasiticus* on the leaf. But, perhaps more generally, the green stem hardens up prematurely, scaly grey patches being formed. These patches are the epidermal layer of the twig which has been cut off by the plant after it has been attacked by the alga. A similar hardening up often occurs in the attacks of fungi, *e.g.* those of Grey Blight and Brown Blight, on the green twigs. These scaly patches usually crack longitudinally, and thus provide a further opening for the attack of the alga. The superficial discs of *Cephaleuros mycoidea* have not been observed on the green stems of tea, though they have been seen on rose stems. The red hairs on the stem arise from the cracks in the outer layers (Plate II., Figs. 4, 5).

Attention is generally drawn to affected bushes by their "thin" appearance. The branches which have developed since the last pruning are weak and spindly, and bear very few leaves. Sometimes the leaves gradually fall off, buds are produced which do not develop far, and the stems die back. These symptoms are due partly to the direct attack of the alga on the leaf stalk, and partly to the general weakening of the stem by the growth of the alga in it. One fairly common and conspicuous effect is the occurrence of variegated leaves, green and white, or green and pale yellow, more particularly towards the outside of the bush. [There is, however, another variegation of the tea leaf which is not

due to Red Rust, but is apparently merely physiological; in the latter the white areas are usually more sharply defined than in the variegation caused by this disease.] If the dying stems, or those with variegated leaves, are examined, they will usually be found to be more or less covered with the red fruiting hairs, especially during the rains.

FIG. 20.—A tea bush attacked by Red Rust.

These appearances are generally observed in Ceylon on bushes nearly due for pruning, and in bad cases the bush may be surrounded by a ring of dead twigs.

The most serious damage caused by Red Rust occurs after pruning. According to Mann and Hutchinson, practically all the tea in bearing in North-East India is pruned during the period, December-March, and the usual method is to cut off the previous year's growth, leaving from one to four inches of new wood. In districts badly affected by

Red Rust the disease generally appears, after the first heavy rain of the season, on the lengths of the previous year's wood which were left in pruning. These pruned stems become red in irregular patches, the colour being due to the fruiting hairs of the alga which are produced in such numbers that they form a velvety pile. The alga is not confined to the wood of the previous year, but may be found on old stems up to an inch in diameter. Mann and Hutchinson state that prior to this appearance of the fructifications of the alga, the new shoots which have sprung from the pruned wood may have shown a lack of vigour and a tendency to a premature hardening.

In the low-country of Ceylon, where bushes are pruned back to a framework of a few thick branches, Red Rust may appear on these branches, an inch or so in diameter, in an almost continuous covering from the pruning cut backwards for a length of six inches or more. As a rule the affected branches do not produce any new shoots, but die back. This effect is often very noticeable in fields attacked by the root disease caused by *Botryodiplodia*, and it is probably to be attributed to the weakening of the bush by the root disease.

In attacks on the stem, as described in the two preceding paragraphs, the alga is living within the tissues of the bark, and is only evident when it produces the red fruiting hairs, which may be only in the last stage of the alga on the dying stem. Infection of the stem must have taken place some time previously. In India, it is believed that infection occurs shortly after the young shoots have acquired a brown bark. In the first stages of bark formation the outer layers of the stem are rough, and more or less cracked, and the spores of the alga, lodging in the cracks, give rise in that protected situation to filaments which penetrate into the living tissues. Though further experiment and investigation are required on this point, it would appear that the older branches are infected by means of spores from the leaves and green twigs before the bush is pruned. Mann and Hutchinson's account of its appearance on the pruned stems in India points to the same conclusion. The alga apparently grows slowly, or remains more or less dormant, in the bark until the bush is pruned, when it develops more

vigorously and produces its sporangiophores. In this connection it is to be noted that whereas a fungus would be injured, or retarded in growth, by exposure to light, the parasite in the present disease, being an alga, is most probably benefited by it. The same appears to hold good in the case of other cultivations ; in cacao the species of *Cephaleuros* which occur in Die-back are most abundant on unshaded trees.

The alga ramifies between the cells of the bark and pushes them apart, with the result that some of the surrounding cells die. The effect of the alga extends beyond the limit of its penetration, and consequently a layer of dead cells is formed between the alga and the living tissues of the branch. If the bush is growing vigorously it may form a cork layer beneath the dead cells, and this cork layer cuts out the dead tissue and the alga with it. In that case the alga dries up and dies, and only a small, slightly depressed scar is left on the branch. But if the bush is weak, its growth is too slow to allow of that. The alga then grows through the layer of dead cells and kills off still more, ultimately in many cases killing the branch.

The facts of the foregoing paragraph support the statement that Red Rust is a disease of weak bushes, and afford a clue to the treatment of the disease. The alga is universally distributed, but it does not become a serious parasite, unless the bushes are, for some reason or other, not in a vigorous condition. If a bush is growing vigorously, it can resist the attack of Red Rust.

Weakness of the bushes may be due to several causes,—lack of drainage, shallow soil, the formation of a hard pan, poverty of the soil and lack of manure, hard plucking, improper pruning, etc. Such of these causes as are remediable must be removed before the disease can be got rid of. Bad drainage is a fairly frequent cause on small patches, while over large areas heavy plucking and cessation of manuring have been the main contributory factors during recent years.

No variety of the tea plant is immune to Red Rust, but, in general, it is held that the pure Assam indigenous types have shown themselves the most susceptible, while Manipuri is the most resistant. But differences in soil conditions will completely reverse this conclusion.

As it has been found that vigorous bushes are able to throw off the parasite, Red Rust must be combated by improvements in cultivation, manuring, and pruning which will lead to the production of stronger bushes.

In pruning, clean pruning, *i.e.* the removal of all weak shoots, is essential. Table pruning, or merely cutting across the top of the bush, is to be avoided, as this method leaves untouched the outer branches which are the most likely to have been weakened by Red Rust. These die off and reduce the size of the bush, and a repetition of this process after each pruning may ultimately kill it. Bushes should not be allowed to run up before pruning, with the idea of strengthening them. as they then produce a large number of stems which compete with one another and are weakened in consequence, and are therefore the more liable to be attacked by Red Rust.

The chief requirement in dealing with this disease is improvement of the bushes by general cultivation and manuring. In India it is recommended that a soluble manure should be applied immediately after pruning, the following being suggested :

For sandy soils	Ammonium sulphate . .	1 cwt.
	Superphosphate . . .	½ ,,
	Potassium nitrate . .	½ ,,
For stiff soils .	Potassium nitrate . .	1 ,,
	Basic slag	1 ,,

The application of potash may be strongly recommended. There does not appear to be any doubt that in the case of tea it favours the production of wood and assists the bush to resist disease.

It would be expected that as Red Rust is caused by an alga, it would readily yield to spraying with copper compounds. But in actual practice it is found that owing to its covering of fine hairs the alga in the fruiting stage cannot be wetted. After spraying, the Red Rust patches have been found to be uninjured or to be killed only at their edges. Consequently, spraying when the fructifications are visible is of little use. On the other hand, good results have followed spraying with Bordeaux mixture or lime-sulphur solution immediately after pruning. The alga may then be destroyed before the hairs appear.

Heavy pruning and collar pruning, taken alone, have not proved successful in dealing with this disease ; a healthy growth may be obtained at first, but if the soil conditions have not been improved the new shoots become infected again. Burning over an affected field has been found useless for the same reason.

The treatment indicated is usually begun at pruning time. In certain cases direct treatment of the disease as early as possible is necessary. This may happen when young plants are attacked, or in case of severe outbreaks on older tea. The badly diseased branches should be cut out and the bushes sprayed with Bordeaux mixture, Burgundy mixture, or lime-sulphur solution. In India it is advised that lime-sulphur solution should be used in the cold weather and Burgundy mixture, with the addition of an adhesive, during the rains. If the soil is poor an application of soluble manure should be given.

It has not yet been decided which of the leaf algae attacks the older stems. Mann and Hutchinson record that the alga found within the bark is green, not red or orange. In Ceylon it is both green and orange, and those are the colours figured by Karsten for *Cephaleuros parasiticus*. It is probable, therefore, that the alga in the old stems is the latter species. On the other hand, the colour of the sporangiophores on the stem is decidedly red or orange-red, while the sporangiophores of *Cephaleuros parasiticus* on the leaf are yellow or orange-yellow.

Bacterial Leaf and Stem Disease

(*Bacillus Theae* Hori and Bokura)

A disease caused by a bacterium which attacks the leaves and stems of the tea bush has been known to occur in Japan since 1908, though its nature was not determined until it was investigated by Hori in 1914. Hori named it " Red Scald Disease." As it is at present only known from Japan, the details which are available concerning its mode and time of occurrence on the bush must be interpreted in accordance with the methods of tea cultivation in that country, where plucking is in abeyance during the winter.

The disease may make its appearance in February-March on the old leaves and twigs of the previous year, or later in the year on the young leaves and twigs of any of the subsequent flushes. It begins first on the leaves and passes from them to the twigs. Practically, it may attack leaves of any age and any twigs which bear leaves. When the old leaves of the previous year have been attacked, the buds which afterwards develop in their axils may prove to be infected.

On fully developed leaves the disease first produces pale brown circular spots, 2 to 3 millimetres in diameter, scattered over the leaf. These spots rapidly increase in size and coalesce, forming large confluent patches. The margin of the patch is somewhat irregular and undulating, but sharply defined. The patches are slightly blackish towards the margin and bear numerous concentric undulating lines. In dry weather they change to reddish brown, while in wet weather they become dark reddish brown. On the under surface of the leaf the spot is pale brown, becoming blackish towards the margin. Spots frequently begin on the mid-rib, extend irregularly from side to side of the leaf, and spread down the leaf-stalk to the twig. The injured leaves rapidly wither, and the diseased bush often loses all its old leaves and becomes naked for a time.

After the disease has occurred on the full-grown leaves, the young buds may be attacked just as they open or shortly afterwards, turning red-brown and finally becoming black.

On twigs which have become woody the diseased tissues turn black only at the points of attachment of the leaves. Young green twigs turn black and wither entirely when attacked, so that bushes which are severely affected become bare and exhibit numerous dead twigs blackened for a length of 4 or 5 inches.

The disease is said to occur only on tea which is exposed to full sunlight. It is not found on tea which is shaded by trees or artificially screened. Correspondingly, on unshaded tea, the upper part of a bush may be severely damaged, while the lower part is only slightly affected.

It has been found that the system of manuring has an important bearing upon the incidence of this disease. In many cases fields had been heavily manured with a

nitrogenous manure, usually nightsoil with the addition of fish or rape cake, in order to obtain an increased crop. Hori remarks that, hitherto, tea manuring in Japan has consisted principally of supplying nitrogen, without any regard to phosphoric acid or potash. The bacterial disease occurs principally upon fields or estates thus excessively manured, and it has been made worse by a repetition of the manuring in the hope of restoring vigour to bushes weakened by the disease.

Wet weather favours the progress of the disease, as the rain washes the bacteria from the spots on the leaf down the leaf-stalk to the stem, where they can attack the stem or infect the young bud.

There is as yet no proof that the bacteria are conveyed from bush to bush by insects, though it is probable that such is the case. The punctures made by mites or sucking insects would afford the bacteria a ready means of entrance into the leaf. It has been noted by one observer that leaves partly eaten by bag-worms are severely attacked, and that the disease appears first on the bushes which have been badly damaged by these insects.

It has been observed that tea which has been sprayed with Bordeaux mixture as a preventative of leaf disease caused by fungi is not attacked by this bacterial disease. Hence it is recommended that the same treatment should be adopted against the latter disease, the bushes being sprayed with Bordeaux mixture (1) at the time the spring buds begin to develop, (2) again after the first flush has been plucked, and (3) a third time, in the autumn, after plucking has ceased.

Excessive nitrogenous manuring must be abandoned in favour of a balanced mixture with a due proportion of phosphoric acid and potash.

Dead twigs must be pruned off and burnt, and it is also recommended that diseased leaves should be shaken off, collected, and burnt.

Black Rot

(*Corticium spp.*)

A disease of this character was first observed on tea in Java in 1907 and was described by Bernard. In 1916

a similar disease was found in Ceylon, and the former has since been recorded for Assam. As far as Ceylon is concerned, it is highly probable that the disease has existed in that country for many years and has been overlooked, probably passed over as a bad attack of one of

FIG. 21.—The effect of Black Rot on Coca: lower leaves decayed, upper leaves healthy. × $\frac{1}{6}$.

the common leaf diseases on bushes nearly due for pruning. Grounds for that supposition are afforded by a perusal of the literature relating to coffee leaf disease in Ceylon, from which it is clear that the coffee was attacked by Black Rot, caused by a species of *Corticium*, in addition to the notorious *Hemileia vastatrix*. Coffee in South India is attacked by a similar Black Rot, but the fungus is a different species from that found on tea in Ceylon.

In its effect on the tea bush the planter would no doubt regard the Ceylon disease as a leaf disease pure and simple. The fungus, however, is not confined to the leaves, but can and does spread over all the parts of the bush above ground. It is therefore impossible to eradicate it by merely plucking and burning diseased leaves, and it is important that its true character should be recognised, so that appropriate steps may be taken to arrest its spread.

Attention is usually directed to the affected bushes by the blackening of the younger leaves. The more tender leaves in the upper parts of the bush turn black and become soft and rotten. Furthermore, they do not immediately fall off, but remain for a long time attached to the shoots. In very wet weather the older leaves may share the same fate, but it frequently happens that the injury on the latter is confined to the production of local dead patches. The dead leaves hang more or less vertically, and, if they come in contact with the stem, adhere firmly to it. Similarly, dead leaves which come in contact with one another become fastened together in clusters, while fallen leaves often adhere to healthy ones. In very bad attacks the numerous, apparently dead, bushes, covered with decaying leaves, present a most deplorable sight.

Although the fungus may have spread over the greater part of a tea bush, it may not be perceptible to the naked eye during wet weather. In that respect the Ceylon Black Rot differs entirely from the Thread Blights, in which the stems and the leaves always bear comparatively stout, white threads of mycelium. The easiest way of detecting the fungus of Black Rot in such cases is to remove a dead leaf from the stem very carefully, pulling it off in a direction parallel to the stem. It will then be found that a thin, transparent film of mycelium peels off the stem, attached to the base of the leaf-stalk.

The foregoing test and the occurrence of clusters of dead leaves fastened together by very fine, cobwebby films of mycelium serve to distinguish Black Rot from severe attacks of Grey Blight.

The fungus which causes the disease consists of very fine threads which run along the stems and over the under surface of the leaves. These threads unite into a very

delicate film, especially on the leaf. The fungus has been found on woody stems up to an inch in diameter, and can no doubt occur on any part of the bush above the ground. On the old stems it does not appear to cause any damage. On the green stems the fungus may cause a premature hardening in the form of scaly, grey-brown patches, or it may ultimately kill them completely. But before that happens the planter will have noted its effect upon the young leaf.

The first sign of an attack on the young leaf is the appearance of a number of small, blackish-brown, or chocolate-brown spots, usually crowded together (Plate I., Fig. 9). The upper surface of the leaf appears sunken on and round the spots. These spots soon run together and form a patch which gradually extends over the whole leaf. Large patches are red-brown to chocolate-brown, usually mottled, becoming black when old and wet.

On the older leaves the effect may not be so general, only part of the leaf being attacked, but this no doubt depends on the weather. If the whole leaf is not involved, the diseased spots are usually large, sunken, black, or deep chocolate-brown with a blackish margin, uniformly coloured or mottled on the upper surface, and greyish brown, somewhat sodden on the lower. When dry the spot is grey, and may easily be mistaken for Grey Blight.

The fungus threads run along the stem and pass to the leaves *via* the leaf-stalk. As far as has been determined, they are confined to the under surface of the leaf, except in cases where a diseased leaf falls on the upper side of a sound one. But even in the latter case the fungus does not appear to cause any damage through the upper surface. The spots may first appear at any point on the leaf, not necessarily at the stalk end, as might be expected. Frequently the fungus accumulates in the axil of the leaf, *i.e.* the angle between the leaf and the stem, and forms a fairly dense, white or yellowish felted cushion, while the leaf and stem are still green.

In addition to the attack on the leaf *via* the leaf-stalk, healthy leaves may be infected by coming in contact with diseased leaves, or from diseased leaves which fall off and adhere to those below. As far as has been observed, the fungus does not produce aerial mycelium, *i.e.* free threads

which stretch across from one leaf to another, as in the case of Horse-hair Blight.

If a shoot which bears one or two diseased leaves be placed in a closed tin box, it will be found, in about twelve hours, to have produced a quantity of greyish, cobwebby mycelium. The growth of the fungus under such circumstances is extraordinarily rapid, and glass dishes in which diseased shoots are enclosed are usually filled with masses of mycelium in a few days. This indicates the possibility of a very rapid spread of the disease under suitable weather conditions, *e.g.* a saturated atmosphere and a high temperature.

Black Rot has only been observed on tea in Ceylon, up to the present, in the wetter low-country districts, and on tea which is due or nearly due for pruning. The disease usually occurs in patches scattered over the field. This would indicate an original distribution by spores, blown to different parts of the field, and a subsequent spread at each point by the growth of the mycelium and the dispersal of diseased leaves by the wind. There is no doubt that the fungus is an inhabitant of the Ceylon jungles and spreads from the jungle to the tea. On one infected estate it was found on an isolated group of jungle shrubs, on *Calophyllum Burmanni* (Sinh. *Gurukina*), of which the clump was chiefly composed, and on *Hemidesmus indicus* (Sinh. *Iramusu*), a climber which overran the Gurukina. There would not, however, appear to be much probability that it will prove to be confined to any particular species of jungle shrubs. In Ceylon it attacks coca (*Erythroxylon Coca*) and *Oxyanthus tubiflorus*.

When the fungus is growing rapidly in the wet season on tea in the low country, the mycelium on the stems and leaves, as already stated, is practically invisible. In drier weather, however, or during the rains at higher elevations, the threads on the stem and the films on the leaves produce fructifications, and they then become conspicuous. These fructifications consist of groups of basidia, each basidium bearing four spores; and owing to their development the films and threads become powdery and white or pale pink. It is remarkable that on tea (low country) these white powdery patches have been found only on the older leaves which show little or no damage from the fungus. On coca, however, the fructifica-

tion has been found also on the dead withered leaves, though on this plant it is still most abundant on living leaves and stems which do not show signs of injury.

When the fungus is producing its fructifications the under surface of a leaf may be covered with a thin, white or pinkish powdery film, either completely, or in patches extending from the leaf-stalk, or in circular patches anywhere on the lower surface. Similar patches are formed on the

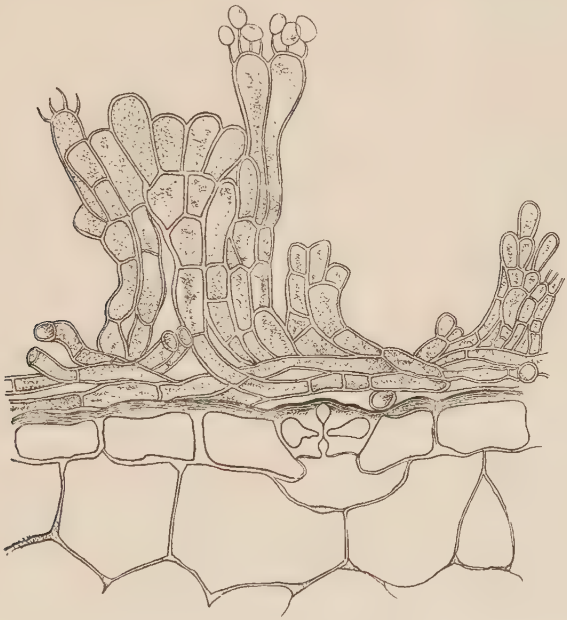

FIG. 22.—*Corticium Theae*, section of the film on a tea leaf, showing the basidia and spores. × 600. (After Bernard.)

stem, where of necessity they must run along the stem and are often confined to the lower side. Hence the fructification on the stem superficially resembles a Thread Blight. It differs, however, from the Thread Blights in that the visible patches are composed entirely of the fructification and are more or less diffuse, and in the absence of a definite, conspicuous, sterile cord. Microscopically it differs completely in structure.

The film on the leaves and the mycelium on the stems are comparatively easily detached when fresh. They run

over the surface of the living tissue, but the hyphae apparently do not penetrate it. Up to the present it is not known how the fungus exerts its effect. The bushes on which it grows undoubtedly suffer; their leaves decay rapidly and the smaller twigs are killed. It has been suggested that the superficial film blocks the stomata and so causes the death of the leaf, but that does not agree with the observed effects.

Fig. 23.—*Corticium* sp. (Black Rot), in fructification on stem of Coca. × ½.

On coca the fungus usually starts towards the base of a branch and grows upwards rapidly, killing off the leaves and binding them to the stem. White powdery patches may be found on these dead leaves. In the further growth of the fungus up the branch, however, especially if the rains temporarily cease, the stem and the upper leaves are covered with white, or pinkish, fruiting patches, and these leaves do not show any signs of injury.

The Ceylon *Corticium* is still alive on prunings left in the field two months at least after pruning. Prunings gathered in June from a field pruned in April yielded an abundance of mycelium when placed in closed glass dishes, and this rapidly produced the characteristic spots on fresh tea leaves put in subsequently. In the same field, and at the same date, the lower branches of some bushes, the new leaves of which had come in contact with the prunings on the ground, had already acquired the disease from the prunings.

As the fungus usually attacks tea near the pruning time, it can be dealt with during pruning. All prunings from infected bushes, and those immediately around them, must be collected and burnt. It is best to prune these bushes first, leaving the healthy bushes to be pruned later. Since the fungus occurs on the branches as well as on the leaves the bushes should be pruned well back. Burning the prunings

is essential, because the fungus can survive on them for some months and can infect branches which come in contact with them, and can most probably reascend the bush from them. The adoption of the above methods will get rid of the greater part of the fungus, but will leave untouched any which is living on the older wood. To eradicate the latter the bushes must be well sprayed, after pruning, with Bordeaux mixture.

In Java a different species, *Corticium Theae*, forms white or pinkish cords which run along the branches, ramifying and uniting here and there. The cords are found only on the young branches, two or three years old, never on the thicker, older branches. The cords are from one-half to 2 millimetres broad, but sometimes spread out into a very thin film. When the cord reaches a leaf-stalk, it travels along it to the under surface of the leaf, which it covers with a thin pink film.

This disease has been found on several occasions in Java, but it has not caused very serious damage there. On some fields, however, a fairly large number of bushes may be found which exhibit the characteristic features of the disease. In the middle of a bush, which is otherwise vigorous and healthy, there may be found a dead branch bearing a cluster of yellow, dried leaves, and on the other branches, which may die soon afterwards, one finds the pale pink cords passing along the leaf-stalks and expanding over the lower surface of the leaves.

Corticium Theae differs from the fungus of the Ceylon Black Rot in having a conspicuous cord on the stem. In the latter respect it resembles the Thread Blights, but it differs from these in the structure of the thread.

Thread Blight

(1) The Parasitic Thread Blight of India

The name Thread Blight is applied to a white mycelium which runs in coarse strands over the stems and leaves of the tea bush. At least one such fungus has been known to exist on tea in India since 1868, and has been the subject of much writing and numerous mistakes. The mycelium,

in the condition in which it is usually collected by the planter, is generally sterile, and partly for that reason the literature relating to Thread Blight consists mainly of conjectures. It is now known that there are at least two species of Thread Blight on tea in India, one of them parasitic and the other epiphytic.

The white mycelium usually begins its development on the branches and spreads from them to the leaves. It may begin at any height from the ground, but in general it appears to originate under the shelter of the dense shade about half-way up the bush. Once it has obtained a footing, it runs along the branches, chiefly in an upward direction. It does not start from ground-level, as a rule, and it is not connected with any mycelium in the soil. On the other hand, the mycelium of *Polyporus interruptus*, which causes a root disease of tea, may run from the diseased root up the stem in cords which closely resemble Thread Blight.

The white thread, which may be up to a millimetre broad, is closely and firmly attached to the bark of the branch. It is at first somewhat woolly, and gives off along the margin very fine hyphae which serve to fasten it to the bark. When old it is usually firm and smooth, and may become brownish. Here and there it branches at an acute angle, the branches frequently reuniting and forming a network. The cords tend to become stouter as they ascend over the thinner twigs at the top of the bush.

When the cord reaches a leaf-stalk it gives off a branch which travels along the leaf-stalk on to the under side of the leaf. As a rule, it divides fanwise at the base of the leaf into a number of finer cords which radiate from the base over the lower surface. These fine strands soon become united laterally by a thin film, so that the under surface of the leaf is covered with a thin white sheet.

If two leaves are in contact the mycelium may pass from one to the other, and Butler records that, in great humidity, it may cross spaces up to half an inch wide.

The effect of this Thread Blight on the leaf is soon evident. In a very short time the part of the leaf which is covered by the fungus turns brown and dies; this is usually the basal part of the leaf, and in consequence of the death of that part the remainder withers. The dead leaf then

becomes detached from the stem, but it frequently remains suspended by the thread for some time. On thin-leaved jungle shrubs, such as *Strobilanthes*, the effect of the fungus is very marked ; and it is unnecessary to turn over the leaves to see whether they bear the fungus, for the upper surface

Fig. 24.—Parasitic Thread Blight on *Gymnosporia*, natural size.

is blackened over an area which corresponds exactly with the distribution of the fungus on the lower.

It has not yet been determined how the fungus attacks the leaf. When fresh and moist, the film can be peeled off the surface, and no hyphae have been detected within the leaf in the early stages of the attack. As, however, the ultimate branches of the hyphae are very fine, it is possible that they may have been overlooked. Hyphae from the cord penetrate into the stem, and, though they do not appear to injure

the tea stem, open wounds or cankers are formed on the stems of jungle shrubs. Young stems are killed by this Thread Blight.

This form of Thread Blight occurs on tea in Northern India, and the same, or a similar, species on coffee in Java and on jungle shrubs in Ceylon. It has not yet been found on tea in Ceylon. It has also been recorded in India on bamboo, loquat, sapodilla, *Duranta*, and *Dillenia indica*, but these records would appear to be based on naked-eye characters only, and in view of the confusion which has prevailed concerning the different species of Thread Blights it is probable that this list needs revision.

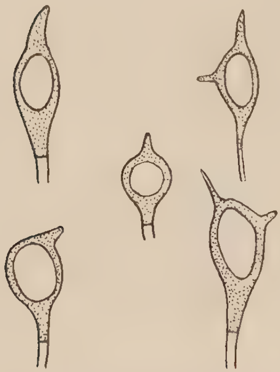

Fig. 25.—Anker cells from the Indian parasitic Thread Blight. ×800.

The parasitic species on tea may, to some extent, be distinguished from the epiphytic harmless species by the thread becoming thicker on the smaller branches, and by the continuous film on the lower surface of the leaf. Microscopically it differs in having peculiar bodies, known as anker cells, on the thread, and, more abundantly, in the film on the leaf. These are oval, or spherical, cells with a basal and an apical point, and sometimes one or more points projecting from the middle.

Thread Blight is not necessarily confined to bushes under dense shade. It can occur on bushes in the open exposed to the full effect of the sun. This at first sight is surprising, as a fungus mycelium is usually a delicate structure and soon succumbs on exposure. In the Thread Blights, however, the bulk of the hyphae of the cord are thick-walled or solid, and because of that the mycelium can withstand desiccation.

Watt and Mann considered that Thread Blight was a very destructive disease. They stated that it occurred in every Indian tea district, and in some of them it had done a great amount of damage. They were of opinion that it had been one of the commonest, and perhaps one of the most destructive, blights of the tea bush, though it had been usually neglected and looked upon as causing little or no injury. In con-

sequence, 20 to 50 per cent of the bushes in a block were not infrequently attacked, thus reducing yields and ruining bushes.

Tunstall, in 1916, stated that the improvement which had taken place in pruning in Assam had resulted in a great diminution in the attacks of Thread Blight in that district. The caustic washes which many planters had used on "cut-back" tea in the cold weather had also tended to further reduction. In consequence, Thread Blight had ceased to be an important disease in most of the tea districts. According to the same author, Thread Blight was very prevalent in Cachar and Sylhet during the rainy season on most gardens, especially on narrow, shaded bheels between teelas. The application of lime sulphur solution, four times the usual strength, during the cold weather had been found quite successful without pruning out the infected wood.

The treatment of the Thread Blight is usually taken in hand at the pruning season. As far as possible all small branches which bear the white threads should be cut out, and if the blight is confined to the upper parts of the bush that will suffice. But if the heavier wood is attacked, the bushes must be treated, after pruning, with lime sulphur wash. This must be brushed over the affected parts, the mixture being well rubbed into the thread. If the threads in the middle of the bush are left untreated they will rapidly grow upwards and attack the new shoots.

The affected prunings must be burnt. If left lying on the ground they may develop the fructification, which will then produce spores capable of reinfecting the bushes, or the threads may possibly spread from the prunings to the bush again. It has been stated that the roots of tea bushes have become infected with Thread Blight after affected prunings have been buried, but in view of the known habits of the fungus, and the difficulty of identifying mycelia, that would appear doubtful. Search should be made for trees or shrubs, other than tea, bearing Thread Blight, in the immediate neighbourhood, and if any are found they should be treated or removed.

When withered leaves which bear Thread Blight are blown off by the wind and lodge in other bushes, the fungus grows from the leaf to any stem with which it happens to be

in contact and thus infects the bush. This is of quite common occurrence in tea, and a dead leaf can often be found attached to a stem at the point where the cord begins. In India, not only tea leaves, but the leaves of a jungle tree, Utengah (*Dillenia indica*), have been found adhering in that way to the stems of the tea bush. But while that method undoubtedly serves to distribute the blight through the field, it may be doubted whether it is effective over long distances or in introducing the disease into new localities. In the latter cases a distribution by means of spores would appear more probable. Up to the present, however, no fructification has yet been discovered either of this Indian parasitic Thread Blight or of the corresponding parasitic Thread Blights of Java and Ceylon.

Thread Blight

(2) The Epiphytic Thread Blight of India and Ceylon

(*Marasmius pulcher* (B. and Br.) Petch)

The common Thread Blight on tea in Ceylon is epiphytic—that is, it grows on the tea bush but does not attack it. The same species occurs on tea in India, but the relative distribution of this and the parasitic species on tea in that country is not known. It has been found also on nutmeg, cacao, and *Beloperone oblongata* in Ceylon, but has not yet been discovered in the jungle.

To the naked eye the white cord on the stem does not differ notably from that of the parasitic species. On the thicker stems it tends to branch fanwise. As a rule, it does not become thicker on the smaller twigs, and it does not form a white film on the under surface of the living leaf. When the thread runs on to the lower surface of a leaf, it usually remains undivided, but if it branches the branches are not united by a continuous film. It passes from one leaf to another if the leaves are in contact, but it has not been observed to bridge any gap. The two leaves are generally fastened together by a thick white pad of mycelium at the point of contact. Microscopically, it differs from the parasitic species in not having any anker cells.

This Thread Blight has been under observation for several years on nutmeg, and has not been found to cause any damage. The leaves over which it runs do not exhibit any signs of injury, and they are not cast off, except at the normal times of leaf-fall. When they are detached they remain for a long time suspended by the thread, and may become adherent to one another, or to a branch, thus forming clusters of dead, withered leaves.

FIG. 26.—Epiphytic Thread Blight (*Marasmius pulcher*) on tea leaf and stem, with a dead leaf attached. $\times \frac{1}{2}$.

In its general details of structure and life-history this Thread Blight resembles the parasitic Thread Blight. Its cords are composed chiefly of thick-walled hyphae; it runs over the tea bush in the same manner; and it can be distributed by means of wind-borne infected leaves. In the case of this species, however, the fructification is known.

The fungus sometimes forms broad, thin expansions at the side of the cord on the stem, and these become covered with minute white cups (Fig. 28), about half a millimetre in diameter. Similarly, after a leaf has withered, the fungus may grow on into a film which covers the under surface

of the leaf, and the same white cups may develop on this film. These cups are the fructifications, but not the fully developed form. The latter is found on leaves which have fallen to the ground, or into the middle of the tea bush, and is a small, helmet-shaped basidiomycete, white above, ochraceous below, with a few gills on the lower surface. It is known as *Marasmius pulcher*.

This Thread Blight often appears on tea which has been allowed to run up before pruning. It does not do any appreciable damage. The varying opinions which have been expressed con-

Fig. 27.—Epiphytic Thread Blight on tea stem. × ½.

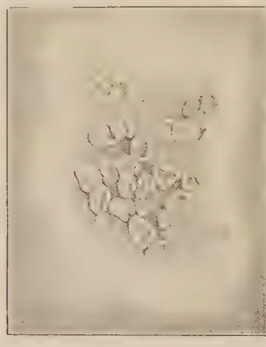

Fig. 28.—*Marasmius pulcher*, "*Cyphella*" form. × 8.

cerning the injury caused by Thread Blight are perhaps to be attributed to the fact that some planters have been acquainted with this species only, while others have had to deal with the parasitic species. It should be treated in the same way as the parasitic species.

White Stem Blight

Another disease which must be classed with the Thread Blights has occurred on tea and rubber in Ceylon. At first sight it seems quite different from the common Thread Blight, for instead of the stems having distinct white cottony threads running along them, they are completely whitened all over. As a rule, the effect is seen above the

level of the old wood, beginning towards the base of branches, 1 to 1½ centimetres in diameter, and extending upwards to the smaller twigs. The whole of the stems in the upper part of the bush look as if they had been whitewashed.

FIG. 29.—White Stem Blight on tea. × ½.

A casual examination of an affected stem does not reveal any general covering of fungus mycelium, such as would be expected from its appearance. The exterior of the stem consists of its original bark, but this is white instead of brown. On closer inspection, however, one or more white or yellowish cords are observed running longitudinally along the stem over the whitened area. These resemble the cords of the common Thread Blight, but, on the thicker stems at least, they are not as stout as in the common form. They are not conspicuous, because of the general whitening of the whole stem.

The peculiarity which distinguishes this disease from the ordinary Thread Blight is that, whereas in the latter the fungus hyphae run in a well-defined cord, in this case they spread out from the cord through the dead outer bark layer of the stem. These spreading hyphae are not visible to the naked eye, as they are of very small diameter and run through and between the dead bark cells. But in feeding on these cells they bleach them, and consequently the stem is covered with a white layer, which owes its colour to the dead and loosened bark cells rather than to the colour of the fungus hyphae.

The cords usually become stouter and more prominent as they ascend the stem, and the smaller twigs may bear cords only, without any general whitening. On reaching the region of the leaves, they give off finer branches which pass

along the lower side of the leaf-stalk to the under side of the leaf, frequently forming a small pad of fungus tissue at the base of the leaf-stalk. Once on the leaf, the cord divides into numerous branches which spread out fanwise, or form a network, over the under surface.

The effect on the leaf is, as a rule, quite different from that of the ordinary Thread Blight. The fungus threads may run regularly over the leaf, or they may expand into minute circular pads at frequent intervals. But, in many cases, the thread is bordered on each side by a narrow watery-green zone, which indicates that the fungus has an immediate effect upon the tissues of the leaf; and a microscopic examination shows that branches from the thread have penetrated into the leaf and are attacking its cells. As the attack develops, the superficial cords become broader and the intervening spaces are often covered with a thin, white film, while the leaf turns brown and dies. The appearance of the dead leaf is quite typical (Fig. 30). The part which bears the fungus threads, extending from the leaf-stalk over half or two-thirds of the leaf, becomes pale yellow-brown, or even pale yellow, and papery or membranous, but the terminal part, which was probably not directly attacked by the fungus, turns the usual dark brown, or grey-brown, of a dead tea leaf, and is of the usual thickness, and brittle. The membranous part of the decayed leaf soon weathers away, and leaves the stalk attached to the stem; or, in cases where a fungus strand has run along the middle of the leaf, the mid-rib with its adhering strand may be left.

Fig. 30.—The effect of White Stem Blight on a tea leaf, $\times \frac{2}{3}$; the paler area is yellow and papery.

Where two leaves touch, the fungus may spread from an affected leaf to a healthy one, and the membranous yellow patch then extends over the leaf from the point of contact. Similarly, the fungus may spread from a leaf to a stem, or

vice versa, while pieces of leaves or stems which fall on the whitened stems become united to them by the fungus.

The fungus does not appear to have any immediate effect on the stem. It permeates the normally dead, outer bark, and enters the continuous cork layer which protects the green, living tissue. But when the outer bark is scraped away, the green living cortex appears healthy, and in the cases hitherto observed, the affected stems do not die back. But a microscopic examination shows that some threads penetrate completely through the cortex and extend into the wood. The diseased branches should, therefore, be pruned off below the white region.

The fructification of this fungus has not yet been found.

Horse-hair Blight

(*Marasmius equicrinis* Mull.)

Horse-hair Blight is the particularly apt name given to a fungus mycelium which is sometimes found hanging in festoons among the upper branches of the tea-bush. It cannot be mistaken for any other "blight," so appropriate is the comparison. The cords of mycelium are black, round, and shining, like black horse-hair (Fig. 31).

The threads may originate on the main stem near the ground, or at any point on the branches, but more usually on those in the interior of the bush. They run upwards over the branches and on to the leaves, being attached at intervals by small brown discs of agglutinated hyphae. Unlike the threads of Thread Blight, they are not attached over their whole length; and a single cord is not necessarily confined to one branch, but may pass from branch to branch, or leaf to leaf, at random.

The fructification of the fungus has the same general shape as a mushroom. It may be produced on the aerial mycelium, though in that situation it is so minute that it is scarcely recognisable. But when branches or leaves covered with a tangle of mycelium happen to have fallen to the ground, it appears in abundance on them in the wet season. Good specimens may also be found on mycelium which is growing at the base of the main stem.

The stalk of the fructification is black and shining, like the horse-hair cord: it may be up to two centimetres long. The cap is red-brown or yellow-brown, hemispherical, depressed in the centre, and marked with four to seven radial furrows, which correspond in position with the gills on the under surface (Fig. 11, *Marasmius equicrinis*).

This species of Horse-hair Blight is known to occur in India, Ceylon, Java and Australia, and probably is to be found throughout the Eastern Tropics. It is common in the

FIG. 31.—Horse-hair Blight on Nutmeg. × ½.

jungles, where it grows over the various shrubs which constitute the undergrowth. As a " blight " of cultivated plants, it has been recorded on tea in Ceylon and India, and on nutmeg and *Hevea* in Ceylon. In general, it may be said to prefer damp, shady localities.

Horse-hair Blight, in Ceylon, is practically confined to the low country, though it occurs sparingly at an elevation of 1500 feet. As a rule, it is only observed on tea which is nearly due for pruning. In most cases it was probably present on the main stems when the bushes were last pruned, but it did not reach the top of the bush until they had again nearly run their full period. Its appearance in tangles in

the upper part of the bushes over a wide area frequently occasions considerable alarm. The fungus, however, is not parasitic, but epiphytic, that is, it grows on the bush but does not derive its nourishment from the living tissues. It may be unsightly, but it does no damage. When the older leaves of the bush die, they remain attached to the mycelium, and any dead leaves or twigs which happen to fall from overhanging shade trees become entangled in it. These give a fictitious appearance of parasitism, which is disproved by careful observation. The fungus obtains its food from the dead outer bark of the older stems, and from the dead leaves and twigs in the tangle.

If leaves or twigs which bear the mycelium are conveyed to other bushes, the fungus will continue its growth in its new situation. The suggestion that the mycelium is conveyed from bush to bush by birds which employ it in building their nests lacks the necessary evidence that it ever occurs in birds' nests; and in the case of tea this method of distribution would appear to be improbable, for, in Ceylon at least, where the bushes are plucked at short intervals, they are seldom adopted by birds as nesting sites. The evidence would appear to indicate that distribution is effected by spores.

Prunings from bushes affected with Horse-hair Blight should be burnt. If left on the ground, they produce the fructifications in abundance, and the spores from these can re-infect the bushes. If the mycelium is present on the main stem, burning the prunings will not get rid of the blight, and it will be necessary to take further measures. Brushing the stems with a piece of coir, or some similar substance, will remove the mycelium; but if it is desired to kill it, lime sulphur solution should be used, applied with a brush to the parts affected, after the bushes have been pruned.

ADDENDUM

BLISTER BLIGHT

While this book was in the press, it was announced that Blister Blight, caused by *Exobasidium vexans*, had been discovered in Japan and Formosa. According to Sawada

(*Trans. Nat. Hist. Soc. Formosa*, No. 59, 1922), it was recorded in 1912 as occurring in the province of Shidzuoka, Japan; but that record proved to be incorrect, the fungus being *Exobasidium reticulatum*. In 1920, however, the true Blister Blight was found in that province, and it is now known to occur in several districts in Formosa. Sawada states that the fungus does not produce two kinds of spores, the so-called conidia being merely mature basidiospores.

CHAPTER IV

STEM DISEASES

Comparatively few stem diseases of tea have received distinctive names. Of those which have, probably the best known is Pink Disease, which attacks woody plants of all kinds throughout the Tropics, and is easily recognised by the pink layer of fungus tissue which covers the affected stems. Another, Thorny Stem Blight, at present confined, as far as is known, to Ceylon, is characterised by the production of black thorns on the stems attacked. Stump Rot, in Ceylon, is applied to the attack of *Irpex destruens* on the exposed upper surface of the pruned main stem, the disease being first evident through the death of the branches in the centre of the bush with the result that the bush " becomes hollow."

As a rule, the other stem diseases of tea are popularly classified as either Branch Canker or Die-back. As far as the cause of a disease is concerned, the two classes are not mutually exclusive, for at least one of the fungi which cause Branch Canker can on occasion give rise to Die-back.

The term " Die-back " is applied to diseases in which the branches are killed back gradually from the tip downwards. A similar effect is commonly caused by root disease, and it is often impossible to distinguish between the two except by an examination of the roots. Die-back, moreover, may be caused by an insect attack, *e.g.* by Scarlet Mite. One form of Die-back, which occurs throughout the tea-growing areas of the Eastern Tropics, and is the result of the attack of the alga, *Cephaleuros parasiticus*, has already been described. Other die-backs, caused by fungi, have been recorded from Northern India and Java. Die-back which is confined to the plucked shoots occurs in Java and Ceylon. In all these

cases it is scarcely possible to distinguish between the different diseases except by a microscopic examination and an identification of the fungus concerned.

The term "Canker" is, or should be, applied in plant pathology to wounds of a definite character, viz. those which extend to the wood and are surrounded by a callus, or cushion of bark, generally more or less gnarled and irregular. The formation of a canker usually takes some such course as follows. The bark is killed by a fungus over an area which often runs longitudinally along the stem or branch. The activity of the fungus may then diminish, and as the normal processes of stem-thickening are uninterrupted except over the injured area, a callus, or rim of new wood and bark, is formed round the wound, the surface of the latter thereby becoming sunken below the surrounding level. The dead original bark may fall out or be forced off by the new tissue, or, if thin, it may persist at the base of the wound and be partly covered by the new bark and wood. Under favourable conditions, however, the fungus may resume activity and attack the advancing border of healthy tissue and kill it back; and the continued repetition of this results in a permanent, gradually enlarging, open wound, surrounded by gnarled, distorted bark and wood, often in a series of successive ridges or terraces. The wood in the centre of the wound, exposed to the weather and the attacks of saprophytic, wood-destroying fungi, usually decays.

Branch Canker in tea was first noticed in Southern India in 1899, and has since been found to occur in most of the Indian tea districts. On the young wood the stems were said to split and crack in every direction, while, on the old wood, an open wound was produced which spread until it ringed the bush and necessitated collar pruning. The Indian disease was attributed to a species of *Nectria*.

In Ceylon, Branch Canker was first reported in 1904, but the symptoms of the disease on which this name was then bestowed were quite different from those of the Indian disease. It was recorded as a disease prevalent on the older branches of the tea bushes, and the following description of it was given: "When the disease is found on the older branches it is almost invariably on the upper surface of

horizontal branches; generally, in fields affected by the disease, the stoutest branches of fine old bushes are damaged. The wound runs parallel to the sides of the branch, and varies in length with the time in which the fungus has been growing in the branch, from two or three to twelve or fifteen inches in length. It may be as wide as the branch, and it

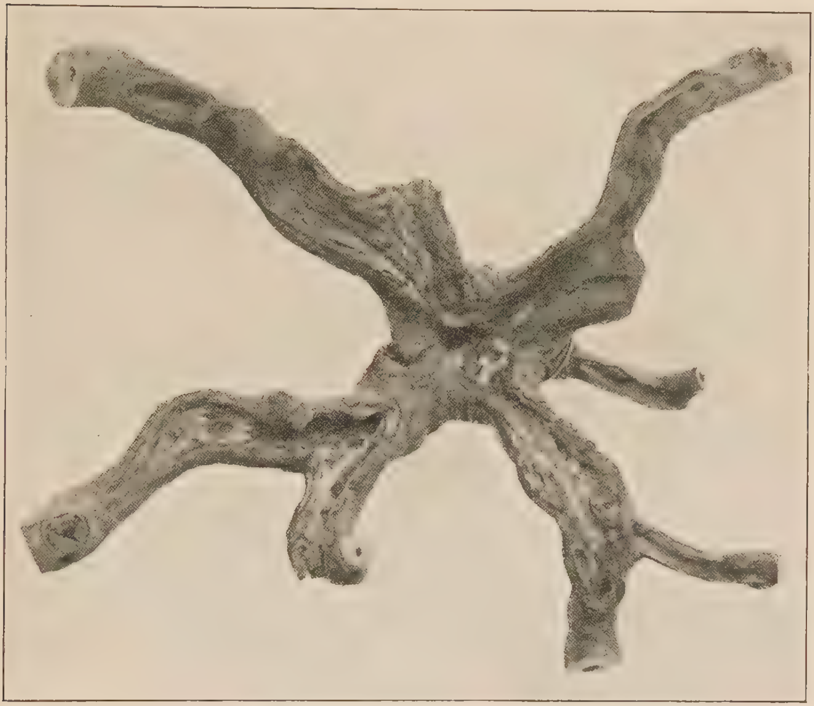

Fig. 32.—Old Branch Canker, viewed from above, $\times \frac{1}{6}$; the wounds extend upwards inside the branches and are seen as holes in the cut ends.

may extend even to the under side. The centre of the wound is, except in wet weather, dry, and the wood is reduced to tinder and can be removed by the finger nail. If the edges of the wound be cut it will be found that in the majority of cases parts of the callus, or cushion of healthy tissue, are discoloured, showing that they are invaded by the mycelium of the fungus" (Fig. 32).

As in India, the disease was attributed to *Nectria*, but chiefly by analogy. It was stated that, though many

thousands of bushes had been searched, no fructifications of *Nectria* had been found in the field, though they had developed on a cankered branch kept in the laboratory for some months. It is not, however, difficult to find several species of *Nectria* on cankered branches, though it by no means follows that they are the cause of the disease.

Briefly summarised, it may be said that any open wound, particularly if bordered by a callus, as wounds on tea usually are, or any gnarled formation on the branches of the tea bush, has come under the general category of Branch Canker. It is only to be expected, therefore, that the name will be found to cover injuries caused by a number of different agents,—fungi and others; and, although the subject still requires further investigation, a few of these causes have been ascertained.

The injuries which have been classed as Branch Canker may be divided into three types, viz. (1) wounds or gnarled formations on young branches (red wood); (2) open wounds, often extending for a foot or more, along the upper surface of old horizontal branches; and (3) wounds on old vertical or horizontal branches which extend along the branch from an old pruning cut. These are not necessarily different diseases, but it will be convenient to consider them separately.

The gnarled formations on young branches and stems are so diverse in shape and appearance that it is almost impossible to give a description which will fit all cases. Sometimes there may be only a series of small wounds on one side of the stem. In other cases swollen areas may occur in discontinuous lengths, the thicker parts being separated by abruptly thinner sections, or the separate swollen areas may be united by narrow isthmuses of the same thickness, either on one side of the branch or on either side at random. The general appearance may give the impression that an extra layer of tissue has been added to the stem, not regularly all round, but in more or less continuous patches; or, where the growth is more nodular, that the stem has "burst" and produced abnormal growth along certain lines or over certain areas.

The reason for these formations is fairly simple. The young, normal, round twig or stem, sometimes when not more than one-quarter of an inch in diameter, is attacked

by a fungus which kills the bark and cambium, not uniformly all round the stem from one end to the other, but in irregular patches, which may be continuous down one side, or encircle the stem here and there, or form an indefinite number of patterns. If the growth of the fungus is arrested, and the stem continues to live and increase in girth, growth in thickness can take place only over those areas where the cambium has not been killed. Hence we get the irregularly arranged new growth, with rounded edges bordering upon the dead areas. If these new growths advance over the dead tissue and coalesce, the irregularity becomes still more marked. Frequently, the first fibrous bark of the young stem, or even the epidermal layer, persists, and forms irregular longitudinal strands overlying the distorted stem and accentuating the general abnormal appearance.

Fig. 33.—Branch Canker on young stems after an attack of Pink Disease. Natural size.

Obviously, in order to produce the effect described, it is essential that the fungus does not enter the wood of the branch to any considerable extent, as by doing so it would kill off the branch completely. One fungus which fulfils this condition is the fungus of Pink Disease, *Corticium salmonicolor*. It has been demonstrated that the mycelium of this fungus can attack wood, but there is abundant evidence that, in the case of the tea bush, it very frequently does not do so in any general manner. It kills the bark and cambium and the wood to a small depth along one side of the stem or in irregularly arranged patches, and as the stem cannot increase in thickness over the dead areas, the typical Branch Canker of young stems results (Fig. 33). Another fungus which produces more or less the same effect is *Macrophoma theicola*, or an earlier stage of this species. This fungus sometimes kills the tissues in small elongated

patches, along one side of the stem or on either side at random. In its subsequent growth, the stem consequently exhibits a number of sunken wounds, the new tissue often forming a netted pattern (Fig. 35).

The wounds on horizontal branches answer to the description already given (p. 89). As a rule, they involve only the upper side, along which they may extend for a foot or more. The wood within the wound is rotten ; and if the branch be cut across, this decay will be found to have penetrated, in many cases, half-way through it. Obviously, to ascertain the cause of this condition, the earliest stages of the disease must be observed. Once the wood is exposed, numerous saprophytic fungi attack it and cause it to decay, and, after the first formation of the hollow, rain water constantly collects in the wound and favours the continuance of the rot. In general, the fungi observed in these advanced stages are such as are commonly found on dead wood.

Both the fungi referred to above can cause Branch Canker on horizontal branches. When the fungus of Pink Disease, *Corticium salmonicolor*, grows along the upper surface of a horizontal branch, it kills the bark and probably part of the wood over an elongated area, and thus initiates the canker. When found in an early stage, the dead bark is generally cracked transversely, and bears white patches, the remains of the pink fructification ; but after the formation of the callus, and the disintegration of the bark, no trace of the *Corticium* is evident.

Macrophoma theicola also attacks the upper surface of a horizontal branch, and similarly kills the bark and wood over a limited area. The affected bark is blackened and soon cracks away from the wood. But before that happens, the extent of the canker is indicated by a slightly raised ridge running along the stem (Fig. 37). The fructifications of this fungus are minute black spheres embedded in the bark ; no part of it is visible externally.

A third cause of Branch Canker on large branches is to be found in the attacks of white ants on bushes previously attacked by Shot-hole Borer. Ordinary wood-destroying fungi obtain an entrance through the holes of the beetle and set up decay, and apparently the fungus which the

beetle cultivates in its galleries assists in the process. The fungus-infested wood is subsequently eaten by white ants.

It may be noted that white ants commonly attack the decayed wood in branch cankers and clean them out. These are generally the ordinary mound-building termites which do not attack living tissues. The termites which attack the living tea bush in Ceylon are usually *Calotermes militaris* or *Calotermes Greenii*, and these form their nests entirely within the stem of the bush.

Wounds which extend from pruning cuts, usually on vertical branches, have not yet been traced to any definite agent. As a rule, such wounds run down the branch in an elongated V, widest at the upper end. Numerous fungi occur on the dead tissue of such wounds, but such as have been critically examined are merely saprophytes. It appears most probable that these wounds are primarily due to the decay of the wood downwards from the exposed surface of the pruning cut.

Descriptions of the diseases referred to above are given in the following pages, and to these the reader is referred for further details concerning them.

In the case of large open wounds on horizontal branches, at least in Ceylon, the fungus which initiated the canker has, in the majority of cases, disappeared before the damage is observed. There is, therefore, little danger of infection from these old wounds, and, consequently, treatment of them may be deferred until pruning time, when it is possible to carry it out more effectively. The main branches which bear large " cankers " on their upper surface must be removed at some time or other. But it is not sound practice, from an economic standpoint, to undertake a sudden crusade against every cankered branch. For years these wounds have very little effect on the crop. The young wood at the ends of the branches continues to flush, and badly cankered fields, where nearly every horizontal limb has been hollowed out, have regularly yielded a thousand pounds of made tea to the acre. To remove every one of these branches at the same time would reduce the crop to a very small figure. They must, however, be removed ultimately, to prevent the rot descending into the main stem. Under the circumstances, it would seem preferable that, as a first

treatment, the worst cankered branches should be removed, and the remainder treated by scraping out the dead wood from the wound and applying tar or some other preservative. At the next pruning, the operations should be repeated, the worst branches being removed as before; and this should be continued at each successive pruning until the field is clean.

Vertical branches which bear wounds extending from the pruning cut can generally be removed when pruning. In districts where this form of "canker" is prevalent, large pruning cuts should be treated with tar, etc., as part of the general routine of pruning.

It is generally held that an excess of potash in the manure applied favours the development of wood. This appears to be substantiated by experience in Ceylon, where numerous examples of the complete healing of branch cankers in their initial stage have been observed from time to time during the last twelve years. But nothing of the kind can be expected when the wounds have become large hollows partly filled with decayed wood.

Finally, it may be noted that Branch Canker has not proved the serious menace to the tea industry which it was presumed to be in Ceylon when first noticed in 1903 or thereabouts. It is probable that, as is so often the case, the injuries then observed were the result of neglect, or indifference, extending over many years.

Branch Canker

(*Nectria* sp.)

A branch canker, attributed to a species of *Nectria*, was briefly described by Watt and Mann in 1903, from specimens obtained in Northern India. It attacks both young twigs and old stems. On the young twigs it causes the characteristic appearance which is known as "Canker" to the tea planter,—the twigs are irregularly thickened, swollen patches of brown healthy tissue alternating with, or surrounding, sunken blackened areas, frequently with thin dead strands of the original cortex overlying the whole and giving it a ragged look. On the old stems, it causes large open wounds

which often spread until they ring the bush. The effect on the young stem has been described as similar to that of severe injury by hail.

The disease has since been investigated by the Scientific Officers of the Indian Tea Association. The fungus is a wound parasite which effects an entrance into the stem through snags, wounds caused by hail or by cattle, etc. The surrounding healthy bark forms a callus round the wound, and thus gives the characteristic lumpy appearance to the diseased twigs. After a short time, small pink cushions, one-sixteenth to one-eighth of an inch in diameter, appear on the bark of the diseased places. These cushions are composed of conidia, the first type of spore. The second type of fructification, the *Nectria*, does not appear until some months later, generally not until after the death of the bush ; it is a minute red sphere which is produced in small clusters on the diseased areas.

The fungus which causes this canker spreads downwards in the wood towards the root, and its mycelium can generally be found in the wood considerably below the point at which the effects of the fungus are made obvious by the death of the buds and the production of the pink fructifications. It is therefore necessary, in dealing with this disease, that in any attempt to remove the infected branches by pruning, they should be cut back well below the point at which the effect is evident externally. Dead thin twigs should be cut off with three or four inches of living wood, and thicker branches with even more. In the case of a badly infected bush, collar pruning is advised. All the cankered prunings must be burnt. Where the disease is serious, a general spraying with Bordeaux mixture immediately after pruning is recommended.

The *Nectria* found on tea branch cankers in India has been identified as *Nectria cancri* Rutgers. The disease may kill a bush in two or three years. It is stated that it can be stopped by pruning out diseased stems and applying lime-sulphur solution immediately.

Branch Canker

(*Macrophoma theicola* Petch)

This stem disease has been recorded only from Ceylon, where it is fairly generally distributed. Its action on the bush is variable: in some cases, or under some conditions, it merely causes Branch Canker; in others it kills back the younger shoots, or the "red wood," and may ultimately travel downwards and kill the bushes completely, especially if they are young. In a few instances it has caused considerable damage in new clearings, about three or four years old, and a large number of bushes have been killed.

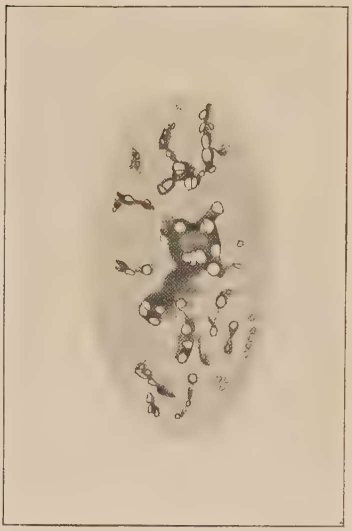

Fig. 34.—*Macrophoma theicola*, pycnidia exposed by shaving a diseased stem. × 10.

The first indications of the disease usually appear in the rainy season, when small, slightly sunken, dark patches may be found on branches about a centimetre in diameter, *i.e.* on the red wood. These patches are usually oval, running longitudinally up the stem for about two or three centimetres, with a breadth up to one centimetre. The bark over these patches is blackened internally, soft and rotten, and separates from the wood easily. In very wet weather it sometimes bears small white or pinkish heaps of spores which are extruded through minute cracks, but this stage of the fungus may not occur. In a later stage, if the diseased bark is lightly shaved, and then examined with a lens, white circular patches, each surrounded by a black ring, can be observed, either isolated or united in groups. These are, in general, sections of the fructification of the fungus which causes the disease. The fructification is a minute black spherical body (pycnidium), immersed in the bark, containing spores which appear white in mass. Hence, when it is cut across, it appears as

a white circular area, bordered by a black line. As a rule, this is a *Macrophoma*, which has been named *Macrophoma theicola*, but another, higher, stage of the fungus may be present, which cannot be distinguished from the *Macrophoma* except by microscopical examination.

In many cases, the activity of the fungus is arrested after

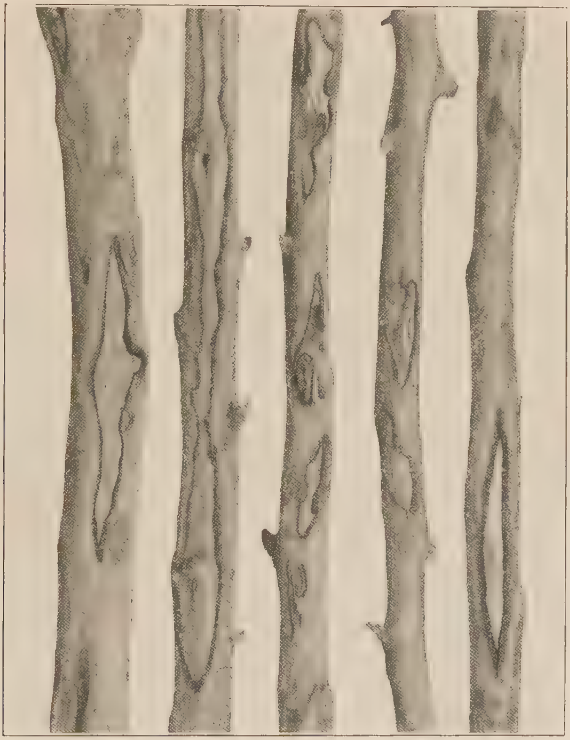

FIG. 35.—Branch Canker caused by *Macrophoma theicola* on the red wood. × $\frac{2}{3}$.

it has killed small areas of the bark, and, in the subsequent growth of the stem, these areas, owing to the death of the cambium, remain depressed below the general level and become surrounded by a swollen callus. The stem consequently bears numerous wounds, or cankers, up to an inch or so in length, often arranged in a longitudinal series along one side. This fungus is therefore one of the causes of Branch Canker, and it is perhaps the commonest cause in the

H

low-country districts of Ceylon. The original bark usually persists within the wound, and the fructifications of the fungus may be found in it.

In other cases, the bark is blackened and killed uniformly down to the base of the branch, and the disease may continue down the main stem and into the root. As the branch dies, the leaves naturally wither and ultimately fall off. In this case the wood is uniformly discoloured, pale brown or greyish brown. The *Macrophoma* fructifications occur in large numbers all along the dead branches, and cause very minute cracks in the surface of the bark. In this form, the disease is a typical "Die-back."

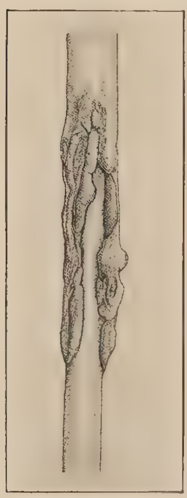

Fig. 36.—Branch Canker caused by an attack of *Macrophoma theicola* at the base of a stem. $\times \frac{1}{2}$.

In old bushes, the fungus often attacks the younger branches, the red wood, at their base. The whole branch may then die off, though the bark and wood are discoloured only in the lowest three inches or so, the death of the upper part being due to the stoppage of its water supply. In many cases, however, only the outer tissues of the lower part of the branch are killed, and the centre is still able to conduct water to the upper parts. Hence the upper part of the branch continues to increase in thickness, and consequently becomes much thicker than the lower part, with a gnarled callus at its lower edge (Fig. 36).

Combinations of the appearances described above are not uncommon. The fungus may at first produce small cankers along the stem, and some months later renew its activity and kill off the cankered branches completely.

Considerable loss has been caused by this disease in young tea which had not been cut down. The bushes consisted of a short main stem which bore three or four erect branches, up to four feet in length. At first, small cankers were formed on the branches, but subsequently the whole branch was attacked and died, and the disease travelled from the branch into the main stem. On some bushes only a single branch

was affected, but in very many cases, all the branches were attacked and the bush died. It is noteworthy that this complete destruction of the bushes occurred in the dry season, and their death was attributed to drought.

Several species of *Nectria* occur on the cankers produced by *Macrophoma*, but they are in all cases saprophytic species which only develop on the dead tissues.

Macrophoma theicola also occurs on the older stems of the tea bush and causes the typical Ceylon Branch Canker of horizontal branches. It attacks the upper surface of the branch, and progresses chiefly lengthwise, killing the bark and blackening it internally, and discolouring the wood to a variable depth. Sometimes the diseased area appears blackish

FIG. 37.—An early stage of Branch Canker on a horizontal branch. $\times \frac{1}{3}$.

externally, but this is usually masked by the covering of lichens, etc., on the branch. The earliest visible indication of the disease is generally the appearance of a slightly raised line on each side of the branch. This line marks the limit of the affected region, and is the beginning of the formation of a callus. Subsequently, the dead bark separates from the wood and falls off, or is weathered away, and the exposed wood rots. As this takes place in the interior of the bush, the early stages are seldom noticed, and by the time the bush is pruned the canker may be in an advanced condition. As already stated, there is little danger of infection from these old wounds, and where many bushes are affected in this way, the injured branches should be removed at successive prunings.

When *Macrophoma* occurs on the smaller branches, treatment should be carried out as soon as the disease is evident.

The fructifications in the dead branches, and in the bark at the base of the wounds, produce spores which will infect other branches, and will convey the disease to the main limbs of the bush. The disease may also travel down the branches into the older stems. Dead branches should be pruned off below the discoloured part, and cankered branches below the wounds. Where the disease is serious, the bushes should be sprayed with Bordeaux mixture after pruning. All dead and cankered prunings must be burnt.

A higher (perithecial) stage of this fungus is often found with the *Macrophoma* stage in the wounds on the smaller stems, and in some cases it has been the only stage discovered in the course of formation of Branch Canker on large horizontal branches. This higher stage has been named *Desmotascus neglectus*: it is indistinguishable from the *Macrophoma* except by microscopic examination.

Pink Disease

(*Corticium salmonicolor* B. and Br.)

Pink Disease is one of the commonest diseases of trees and shrubs in tropical countries. Originally described from Java, it is now known to occur throughout the tropics, and has been recorded as a parasite on about one hundred and fifty species of wild and cultivated plants. It apparently causes more serious damage in Java than in other countries, though it has given great trouble on *Hevea* in the Federated Malay States. It is called "Pink Disease," because the fungus forms a pink covering over the affected stems. In Java it is known as Djamoer Oepas.

Attacks of this disease on tea are comparatively infrequent, and in Ceylon they generally occur at the higher elevations. The first signs of the disease usually appear on the younger woody branches, which lose their leaves and die back. This may occur all over the bush, but in perhaps the commoner case only the branches at the outside of the bush are affected. The latter would appear to be the rule when the bushes are so large that they crowd one another. The fungus travels down the branches towards the centre of the bush, so long as conditions are favourable to its growth.

The disease is readily identified by the thin pink incrustation which it forms on the branches (Plate II., Fig. 6). This is at first continuous, but it afterwards cracks into small fragments, the cracks being more or less at right angles to one another. The incrustation may clothe the twig uniformly all round, or, more generally, it may be confined to its lower, or more shaded, side.

In addition to the pink sheet, which is the fructification, the fungus may be present in two other forms. One of these, which precedes the pink incrustation, consists of a number of fine silky threads united into a thin film. This overruns the branch, and is generally to be observed as a continuation of the pink sheet when the fungus is growing actively. In other words, the fungus generally begins as a series of fine silky threads traversing the branch, and the pink fructification develops later on the film formed by these. The third form of the fungus consists of minute pink cushions which are produced in cracks in the bark: this form appears to be uncommon on tea.

The mention of fine silky threads in connection with Pink Disease has led some readers of mycological literature to class it with the Thread Blights. It does not, however, bear any resemblance to Thread Blight. In the latter, the white or pinkish threads which overrun the branches and leaves are stout cords, visible to the naked eye from some distance, but the silky threads which constitute the first stage of Pink Disease are distributed in an extremely thin film and are barely perceptible unless the branch is examined closely. The Pink Disease fungus is not found on the leaves, as the Thread Blights are.

In some cases, the mycelium of the fungus permeates the bark and the wood, and the twig or branch is completely killed. But in many instances the bark is killed in patches, and if the fungus penetrates into the wood where the bark is dead, it does not cause sufficient injury to kill the branch. When such a branch, in the normal course, increases in thickness, growth takes place only over those areas on which the bark has not been killed, and hence it becomes irregularly swollen, cushions of new tissue with a rounded edge surrounding sunken wounds. This is the typical Branch Canker of small branches or twigs; it has been observed, as a result

of Pink Disease, on twigs down to one-tenth of an inch in diameter (Fig. 33). The dead bark is not cast off, but remains at the bottom of the sunken areas, ragged and fibrous on the younger twigs, or smooth and blackened on the larger. The pink tissue loses its colour when old and becomes white; as a rule, it dries during the dry weather and disappears, but a careful examination with a lens will generally reveal minute patches still adhering to the dead bark.

This localised killing of the bark, without the total destruction of the branch, often leads to the production of very curious malformations. In one instance, the fungus had travelled down, and killed the bark, on a vertical stem, but had not attacked the lateral branches which sprang from it. These lateral branches continued to increase in thickness, while the main stem did not; as a result, each lateral branch developed at its base a collar or flange overlying the main stem.

On the older branches of tea, the fungus may grow along the upper surface and kill the bark over a comparatively narrow area running lengthwise of the branch. When the fungus ceases to grow, the branch develops a swollen margin round the wound, and thus the typical canker of thick branches is produced. The dead bark persists for some time within the canker, and often shows the superficial fungus patch, generally bleached white. If the bush is vigorous, the wound may heal over completely; and experience proves that an excess of potash in the manure applied is of great assistance in promoting this recovery. But in most cases, water lodges in the wound and assists decay, while other fungi, otherwise harmless, grow on the dead bark and wood and gradually hollow out the branch.

Attacks of Pink Disease on tea in Ceylon usually occur towards the close of the monsoon rains. The disease is propagated by spores which are produced on the surface of the pink patches. The fungus belongs to the *Basidiomycetae*, and the pink patch consists of erect basidia perpendicular to the bark, closely packed together and each bearing four spores. Its occurrence in any new locality is no doubt due to wind-borne spores blown from some spot where the fungus exists. The fungus, however, is so widely

distributed, and is found on so many kinds of plants, that it is not possible to prevent its attacks by removing any particular kind of tree or shrub. The disease appears to be worst on tea bordering on, or partly surrounded by, jungle, and it generally makes its appearance on bushes two or three years from pruning.

Affected branches should be pruned off and burnt. As the extent of an attack on a bush can be clearly seen, it might be considered that the removal of all branches which bear the fungus would be sufficient to eradicate the disease. But experience has shown that that is not the case. In practice, Pink Disease has proved very difficult to get rid of, and even when the pruning has been most carefully carried out, it will often recur during the next wet season. It must be strongly advised, therefore, that, after the pruning, the pruned bushes and those surrounding the affected patches should be sprayed with Bordeaux mixture.

Die-back

(*Nectria cinnabarina* Fr.)

A die-back of tea caused by a *Nectria*, *Nectria cinnabarina* Fr., has been recorded from Northern India. The bushes attacked by the fungus become moribund, but rarely die completely. The stems die back, and the new shoots which arise lower down are generally thin and weak. Healthy shoots may in some cases spring up from the collar, but these are soon attacked and reduced to the same state as the older stems. The general appearance of the bushes is similar to that of bushes badly attacked by Red Rust.

The fructifications of the fungus appear on the diseased shoots, sometimes before, but usually after they have died. The first form which is produced consists of small pink cushions, about one-thirty-second of an inch in diameter, and these are generally present in large numbers. This is a conidial form, which bears spores on the surface of the cushions. Subsequently, a perithecial stage appears which consists of minute dark red spheres, either singly or in groups, sometimes attached to the conidial cushions, but more usually separate from them. This perithecial form is

a *Nectria.* Each sphere is from one-fortieth to one-fiftieth of an inch in diameter, and contains spores enclosed in asci.

Inoculation experiments have shown that the fungus can attack wounded shoots but not uninjured ones. In practice, however, this difference is unimportant, as the fungus can enter the shoots through the wounds caused by plucking.

It has been found that this disease is prevalent in the neighbourhood of certain trees, especially Utis (*Alnus nepalensis*) and Umphi (*Pyrularia edulis*), and considerable damage has been caused on some estates where Utis trees have been planted as wind belts. In other cases, species of *Erythrina* have proved to be centres of infection. Investigations have shown that the *Nectria* attacks the flowering shoots of these trees, and spreads from them to the tea.

Consequently, in dealing with this disease, it is necessary, in the first place, to remove trees which are known to harbour the fungus. The diseased bushes should then be pruned back to good wood, and sprayed with a fungicide immediately after pruning to protect the cuts from possible infection. It is essential to cut well back below the dead parts, as the fungus is present in the stem some distance below the part which is evidently diseased. All the prunings should be burnt immediately on the spot.

Die-back

(*Stilbella Theae* Bernard)

A die-back, caused by *Stilbella Theae*, has been recorded from Java by Bernard. On the bushes affected, the leaves of some of the branches withered, and the branches dried up and died. This effect spread from branch to branch until the bush died completely. The bushes were attacked singly or in fairly large groups.

On the diseased branches, there soon appeared large numbers of fructifications in the form of minute orange-red stalks, expanded above into a small head. In some cases these made their appearance even before all the leaves had withered and fallen. They occurred on all the branches attacked, and were sometimes so numerous as to cover the branch with a velvety layer. The single fructification is less

than a millimetre high. Its stalk is red,—dark red-brown at the base, becoming clear orange-red above; the head is globose and rose-coloured.

It is stated that this disease is not generally dangerous, but may become serious in some instances. Badly diseased bushes should be uprooted and burnt. On bushes less seriously affected, the diseased branches should be pruned off and burnt. Pruning cuts should be tarred, as it is probable that the fungus obtains an entry through wounds. The pruned bushes, and those in the immediate neighbourhood of the diseased patches, should be sprayed with Bordeaux mixture.

The disease is worst on low-lying, badly drained land.

Die-back of Plucked Shoots

In the ordinary course of plucking, where a length of the plucked shoot bearing one or two leaves is left on the bush, the subsequent new growth arises from the bud in the angle between the stem and the uppermost leaf. This process is continued at each plucking, so that the extension of the twig takes place in a zigzag or angular fashion, though this is not noticeable on the matured twig, because it straightens out as it becomes woody. The short length of green stem which was left above the uppermost leaf dies and falls off.

Fig. 38.—Die-back of plucked shoots. × ½.

In some cases, however, the whole of the plucked shoot blackens and dies back to its base. A new shoot is then produced at the base of the dead shoot from the woody part of the branch. This second shoot, in turn, may die back when plucked, and be succeeded by a third shoot from the same spot, and the process may be continued until a brush, or crow's foot structure, of dead shoots, or rather half-shoots, is formed at the tip of the branch. As a frequent variation of this, one shoot may develop normally after four or five have died back, and this may be attacked by the disease later, with the consequent formation of another

structure of the same kind higher up; the brushes of dead shoots are situated, in this case, both at the end and the sides of the branch.

Pestalozzia Theae, the Grey Blight fungus, has been found on the dead shoots in several cases of this die-back, and it is probable that this fungus is one cause of it. Bernard has recorded a similar blackening and dying back of plucked shoots in Java, but he does not describe the death of successive shoots which leads to the formation of a brush; indeed, he states that in the case referred to by him, new shoots are produced after the death of the first, and the disease does not progress further. Consequently, the damage done in such cases is not serious. It is, however, of interest to note that among the parasites found by him on the dead shoots were *Pestalozzia* and *Cephaleuros*. Bernard suggests that the spores of *Pestalozzia*, etc., may be transferred to the broken end of the shoots by the plucker: if the plucker were to touch a *Cephaleuros* patch or a heap of *Pestalozzia* spores, she would very probably inoculate the shoot plucked next. But in view of the fact that neither of these organisms occurs, as a rule, on the shoots which are being plucked, this explanation would appear doubtful. Nor does it appear to be required, seeing that the spores of both are usually common on the older leaves and can be easily distributed by the wind.

In one occurrence of this type of disease in Ceylon, the fungus which was present on all the dead shoots was *Didymostilbe Coffeae*, a species which was first discovered on twigs of coffee in Java. The shoots are covered with minute erect hairs which, when viewed with a lens, are seen to be short white stalks, surmounted by an oval, or spherical, reddish head. These hairs, which are the fructifications of the fungus, are only about a millimetre high, but they are easily seen when the shoot is held up to the light. They resemble the fructifications of *Stilbella Theae*, but have spores which are divided into two parts by a cross-wall (Fig. 5).

The attacks of these diseases observed in Ceylon have usually occurred on tea which was due for pruning, or which had been allowed to run beyond the normal pruning time. They may be taken to denote a lack of vigour in the bushes,

which renders the green shoots less able to withstand the wound parasites which may develop on the cut surface. No instance has been recorded of their reappearance after pruning. Their occurrence may perhaps be regarded as a sign that the system of cultivation practised is insufficient.

Thorny Stem Blight

(*Aglaospora aculeata* Petch)

This disease has been known in Ceylon for several years, and is generally distributed in some districts, but it has not been found to cause any great damage. As a rule, it kills off single branches, from one to two inches in diameter. It is readily recognised by the black thorns which are produced on the dead branches. These thorns are the tops of the fructifications of the fungus, and they are arranged either in straight lines or in more or less concentric circles, each thorn being surrounded by an area of slightly raised and cracked bark. In general, they occur in patches three or four inches long.

Fig. 39.—Thorny Stem Blight. ×$\frac{3}{4}$.

The fungus apparently enters the branch through the pruning cut and works downwards in the wood towards the main stem. The affected wood is usually hard, and is coloured uniformly brown. Diseased branches are brittle and easily broken off, so that it is probable that the disease may escape notice owing to the dead branches being broken off accidentally by the pluckers.

The fructification of the fungus is formed within the bark, and as it develops it raises the outer layers and causes them to crack. The black apex projects about a millimetre above the surface and constitutes the characteristic thorn.

If not treated, the fungus spreads into the main stem and ultimately kills the bush. The specimen figured was taken from such a case, the thorns there being borne on a piece of the main stem.

Dead branches should be cut off and burnt. It will be necessary to cut out all the discoloured wood in order to secure the removal of all the fungus, and in many cases this will entail collar pruning.

Massaria theicola Petch

The most general symptom of this disease is the gradual death of the upper parts of bush, branch by branch, often accompanied by the production of new shoots at the collar. The affected branches may die gradually, the leaves withering and falling off and the branch slowly dying back to the base, or they may wilt suddenly, a branch which is green and vigorous in the early morning having all its leaves limp and drooping before midday, just as though it had been cut off and left exposed to the sun.

This disease has hitherto been recorded only from Ceylon. There it has occurred, chiefly in mid-country districts at an elevation of from 2500 to 4000 feet, on tea from three to ten years old. It is not associated with any particular type of soil, though probably the majority of cases have been on patana land. It has not, however, proved a very general or widespread disease, and few cases have been met with during the last ten years.

On digging up an affected bush, the roots are found to be perfectly clean and healthy. This disposes of any suggestion of root disease. Indeed, the production of new shoots at the collar is strong presumptive evidence that the cause does not lie in the roots.

As already stated, the death of a branch sometimes occurs quite suddenly. But the progress of the disease to such an extent as to involve the death of another branch on the same bush is usually slow. In other cases, the leaves turn brown and wither back from the tips, or they become yellowish and

fall off, leaving the branch leafless. After a short time new shoots may arise along the branches, but these are always yellowish and sickly, and they gradually die back until the whole of the branches are dead. But the death of the bush as a whole is of rarer occurrence than that of single branches. Whatever the earlier symptoms may be, a growth of healthy shoots nearly always takes place from the collar, or lower part of the stem, after the upper part is dead.

There is no external evidence of the fungus on the stem or branches, but if the bark of the main stem is scraped certain areas will be found to be blackened internally, and if the wood underlying the blackened bark is cut it will be seen to be a rather dark brown. The best way of observing the effect of the fungus is to saw through the main stem longitudinally, so that the cut passes through the part where the bark is discoloured. If the cut has been properly directed the presence of the fungus in the stem will be immediately evident. The wood, in part at least, is the colour of walnut wood, and contrasts strongly with the yellowish or white colour of the healthy parts. If the whole bush is dead the discoloured area may stretch completely across the section, but in cases where only some of the branches have died, it is usually confined to one side, running vertically down the stem and extending to varying distances across it.

FIG. 40.—Longitudinal section of a stem attacked by *Massaria theicola*. × ½.

If very thin layers of bark are cut off the blackened areas, minute white circular patches may be detected in it with the help of a lens. These are the fructifications, or rather the contents of the fructifications, of the fungus. But they resemble those of *Botryodiplodia* or *Macrophoma*, and cannot be distinguished from the latter two without a microscopical examination.

The fungus lives entirely within the wood and the bark, and forms its fructifications in the latter. Its hyphæ permeate the vessels and fibres of the wood and cause the discoloration already referred to. The wood does not look decayed; it is almost as hard as normal wood. The death of the bush is brought about, not by the disintegration of the tissues, but by the stoppage of the water supply.

In some cases the fungus appears to attack the stem first of all at some distance above the ground. It then advances both upwards and downwards, keeping in many cases to one side of the stem only. Thus in Fig. 40, which illustrates a longitudinal section of a forked stem, it has progressed along one side and killed off one branch, while the other remains quite vigorous. It sometimes happens that the mycelium advances across the base of a small branch and cuts off its water supply, thereby causing it to wither and die without actually entering it. When the spread of the fungus is more general from the beginning, there may be a general defoliation, followed by an unsuccessful attempt to produce new shoots over the whole bush.

Infection appears to occur through slight wounds on the stem, or through the stubs of small branches. Instances have been observed in which the disease began from the pruning cut at the top of a stump; for that reason the disease is sometimes a serious one in young tea which has just been cut back.

The disease appears to be most prevalent in dry weather. This is due to the fact that the growth of the fungus hinders the supply of water, and though the bush can struggle on during the rains when its demands for water are at a minimum, it succumbs as soon as the dry weather necessitates a greater supply. Infection is conveyed by spores which are expelled in a small drop from the fructifications in the bark, and it is most probable that this occurs during the rains.

The dissemination of spores must be prevented by cutting out and burning the diseased parts. It is, however, not sufficient to cut off only the dead branches, as the fungus is not confined to these. In practically all cases the fungus is in the main stem, and the bush must be pruned off low enough to remove all of it. The colour of the diseased wood renders the affected region easily recognisable, and the pruning

must go below that. The section should be examined to ascertain whether all the discoloured wood has been removed, and, if not, it must be pruned lower. If the disease has descended into the root the bush should be dug up and burnt. In the case illustrated in Fig. 40, a cut just below the fork would have ~~been~~ shown discoloured wood over half the section, and it would be necessary to cut still lower. This is a case in which the disease is well advanced, and is in fact already below the ground level.

Where the disease is prevalent, pruning cuts should be tarred, or covered with some other preservative.

Stump Rot

(*Irpex destruens* Petch)

The name "Stump Rot" has been used in some countries as a synonym of "root disease." It is employed here, however, in what would seem to be a more correct sense, viz. to denote a decay which sets in from the top of the main stem in old bushes.

In the case of the present disease, specimens are most generally submitted for examination with the information that the bushes are dying out in the middle. That is the symptom which attracts the attention of the planter. On a large old bush, which is built up of numerous branches arising from a short, stout main stem, the branches in the centre of the bush die, and this condition gradually extends outwards until the bush "becomes hollow." Naturally this particular effect is more likely to occur in up-country districts, where the bushes are in general larger than in the low country. In Ceylon the disease has been recorded only from the highest elevations.

The type of bush attacked is one which consists of a stout main stem, 3 to 4 inches in diameter, from which the branches arise laterally—that is, a bush has been pruned, when full-grown, low down on the main stem. The disease has not been observed on bushes the main stem of which forks into several stout branches.

On examining a diseased bush it is found that the wood at the top of the stump is soft and rotten and of a yellowish

colour. The decay goes on most rapidly in the centre, so that the region affected is more or less cup-shaped. In some cases a hollow may be formed, but in others the rotten wood remains *in situ.* As the disease progresses it ultimately attacks the outer layers of the wood and the bark, beginning with that at the upper edge of the cup. Consequently the branches which are attached to the main stem at its highest point die first, and these are the branches which form the centre of the bush. As the rot extends farther down more

FIG. 41.—*Irpex destruens* on a tea stump. $\times \frac{1}{3}$.

branches are killed, and thus the " hollow " or vacant space in the middle of the bush gradually increases.

The fructification of the fungus which causes this decay in the up-country districts of Ceylon is seldom found on the bushes in the field, though it would no doubt develop on the rotten stump when the bush has been killed out completely. It forms, on the side of the stem, an irregular plate which bears horizontal brackets at its upper edge and over its surface. Small fructifications may consist of a plate about an inch across, with a horizontal bracket at its upper edge; large examples may be several inches across, and bear these

PLATE II.

STEM AND ROOT DISEASES

FIG.

1. Red Rust, epiphytic form, on a tea leaf.
2. Red Rust, a superficial alga patch. × 12.
3. Red Rust, parasitic form on a tea leaf.
4. Red Rust on a tea stem.
5. Red Rust on a tea stem, showing the sporangiophores. × 12.
6. Pink Disease (*Corticium salmonicolor*), fructification on a tea stem.
7. *Irpex destruens*, fructification showing upper surface.
8. *Septobasidium* sp. (parasitic), young advancing edge of fructification on a tea stem.
9. *Septobasidium* sp. (parasitic), older part of the same fructification as Fig. 8.
10. *Poria hypolateritia* (Red Root disease), fructification on a tea stem.
11. *Poria hypolateritia*, red mycelium on a tea root.

All natural size, unless otherwise stated.

STEM AND ROOT DISEASES.

brackets one above the other from top to bottom. The upper surface of the horizontal brackets varies in colour from red-brown to pale ochraceous, and is frequently zoned with these colours (Plate II., Fig. 7); the under surface and the vertical plate overlying the stem are pale ochraceous. The brackets are thin and tough, and the upper surface is usually radially ridged. The under surface of the bracket bears numerous downwardly-directed teeth, and these also cover the vertical parts on the stem: the teeth are triangular, flattened, and up to 4 millimetres long. From the shape of the fructification the fungus is an *Irpex*, and it has been named *Irpex destruens*.

This fungus is very common on stumps and logs in up-country jungles in Ceylon, generally on stumps of trees which have been felled. It is primarily a fungus which attacks dead wood, and it is only known as a parasite on tea in cases where a very large pruning cut has been left unprotected, so that it could obtain a footing on the exposed wood. Obviously its attacks would be prevented if the cut were protected by tar or some other preservative, and this should always be done when large bushes are pruned low down. Bushes which have already been attacked in this way should be collar pruned and the wound tarred.

Neglect to protect such pruning cuts inevitably exposes a large surface of inert wood and affords a nidus for many species of fungi which are otherwise harmless. It may, consequently, be expected that the condition described above, viz. the gradual death of the bushes from the centre, will be induced by the attacks of other fungi than *Irpex destruens*, the particular species varying according to the district. *Irpex destruens* happens to be a common stump fungus in Ceylon up-country districts. In Darjeeling a similar condition has been recorded by Watt and Mann, under the name of Darjeeling Stem Blight. Their description is as follows:

"In the higher parts of the Darjeeling district there will be noticed, on almost every garden, a number of bushes dying from the centre, apparently without reason. It was never noticed below 4000 feet, and appears often on isolated bushes all over the property. In some gardens it is one of the most serious blights on the place. On cutting one of the stems which is dying, the centre of the wood appears to be

turning black, and this appearance, we are informed by Dr. Butler, is due to a fungus attacking the stem."

No further information has been published regarding this Indian disease, and the details given are insufficient to enable any definite conclusions to be arrived at, but it would seem probable that this is another disease which should be classed as Stump Rot.

Velvet Blight, etc.

(*Septobasidium* spp.)

In the Tropics one often finds the branches of shrubs and trees encrusted by a fungus without suffering any apparent damage. The commoner forms of these fungi completely clothe a branch with a rather loose covering, 1 to 2 millimetres thick, for a length of a foot or more, and, on shrubs in the jungle, they may spread from the stem to the leaves. Several of these occur from time to time on the tea bush, and sometimes alarm the planter by spreading over all the upper branches. They vary in colour, but are generally brown or purple-black, not brightly coloured.

One of the commonest species of this habit on tea in Ceylon is readily distinguished from all other fungi which occur on the tea bush by its extraordinary structure. It forms at first a thin brown, or purple-brown, layer over the stem, and from this layer there arise a large number of very slender, erect, rigid brown bristles up to about 2 millimetres high. On the tops of these bristles another continuous layer is formed, thin, but denser than the basal layer, so that the main mass of the fungus is more or less free from the stem and is supported by numbers of rigid hairs. These hairs can be seen at the edge of a patch where the fungus is extending. The colour of the upper layer is usually brown, inclining to grey. The hairs are brittle and easily broken; hence the covering usually becomes torn and ragged.

There is another species of similar structure common in Ceylon jungles, in which the hairs are black and the general colour purple-black. This species often occurs on orange trees.

These fungi belong to the genus *Septobasidium*. Many

species of this genus have the peculiar two-storied structure noted above, though in some the supports of the upper layer are columns rather than hairs. But there are also in the same class species which only show the double structure under a microscope, and consist of alternate layers of loose and dense tissue. These usually form continuous sheets, loosely woolly within, but with a smooth outer surface: when old the surface generally cracks. One of these denser species is common on tea in Ceylon, generally at the base of branches about half an inch in diameter. It is purple-black, and looks like a compressed piece of wadding wrapped round the stem. It is often mistaken for the mycelium of *Rosellinia*, but it does not run up from ground level as the latter would.

Fig. 42.—*Septobasidium* on a tea bush. $\times \frac{1}{2}$.

A species very similar to the last occurs on tea in Northern India and has been named Velvet Blight. When fresh it is blue. It occurs on suberect stems up to about an inch in diameter.

Another Ceylon species found on tea is illustrated on Plate II., Figs. 8 and 9. This is more compact than the commoner species. The margin is slate-coloured or French grey, transversely zoned, with the outer advancing edge white. The older parts are purple-grey or brownish grey, and crack into minute rectangular portions. This species was found on seed-bearers, where it clothed the long stems for a length of several feet.

These species of *Septobasidium* do not grow up the stems of the bush from the ground. Like the Thread Blights and Horse-hair Blights, they begin to grow on the branches and advance thence upwards. But the peculiar feature in their life-history is that they are not, at first, parasitic on the bush. They live on colonies of scale insects on the stem and kill them. If the fungus is scraped off the stem the remains of the scale insects will be found as small white patches lying on the bark, and, as a rule, the stem beneath will be found to be healthy.

These fungi are consequently beneficial, in that, when a bush is badly infested by scale insects, they grow over the insects and destroy them. The purple-black Ceylon species already referred to, which occurs at the base of tea branches, appears to show a preference for the insect *Chionaspis biclavis*.

Unfortunately, however, these fungi in many cases fail to maintain their reputation. After the colony of scale insects has been destroyed, they may attack the stems of the bush and kill them. This occurs in India in the case of Velvet Blight, the hyphæ of which penetrate through the bark and into the wood, chiefly along the medullary rays. Similarly, the Ceylon species figured on Plate II. killed the tea stems after it had finished off the insects. The same effect is reported from Japan, where several species of *Septobasidium* have now been proved to be parasitic on plants. In that country *Septobasidium Acaciæ*, which occurs on tea and *Acacia*, is known to kill the latter; *Septobasidium pedicellatum* attacks the mulberry; and a species of a slightly different genus, *Helicobasidium Tanakæ*, attacks tea and many other plants.

Consequently, although in many cases these fungi are assisting the planter by killing scale insects, they must be got rid of, lest they subsequently attack the tea. No case of serious injury caused by them has been recorded in Ceylon, but in Northern India Velvet Blight has spread rapidly and has done considerable damage.

Dead branches which bear the fungus should be cut off and burnt. Where the bushes are infested, but the branches have not been killed, the fungus should be brushed off, after pruning, using Lime-sulphur mixture or one of the caustic

soda washes. In India it has been found that the best method of dealing with Velvet Blight is to spray in the cold weather, after pruning, with copper-soda emulsion to kill the fungus, and, a few days later, to brush off the dead fungus and spray the bushes again.

Where these fungi are prevalent, obviously one method of preventing their attacks is to treat those bushes which are infested with scale insects with an insecticidal wash, and so remove the host on which they first obtain a footing.

The Grey Fungus of the Dadap

Under this title Bernard has recorded a disease which attacks dadaps in Java, and passes from the dadaps to the tea. He states that it has not caused serious damage on tea, but where the tea is interplanted with dadaps the planter should look out for it. When the fungus attacks a large branch it forms a grey patch, circular in outline and clearly defined, which extends gradually from a central point. When on a small branch it completely surrounds it with a grey ring, and the part of the branch above the ring dries up.

A similar fungus has been found on dadaps in Ceylon on one occasion only. The Ceylon fungus is a species of *Septobasidium*. It grew on branches about $1\frac{1}{2}$ inches in diameter, and formed oval patches up to $3\frac{1}{2}$ inches long and 3 inches broad. These are grey, or purple-grey, with a whitish margin, smooth or slightly broken at the margin where the upper layer is not yet completely formed. The patches are up to a millimetre in thickness, and have the usual two-storied structure, though this is scarcely evident without a microscopical examination. This fungus has not yet been observed to cause any damage.

Ringing of New Shoots from Collar-pruned Bushes

Collar pruning—*i.e.* cutting across the main stem at ground level—is an operation which one reads about but seldom sees nowadays, though there is evidence on many estates that it was formerly more general. From a mycological point

of view it is fortunate that the practice has fallen into disfavour. When a bush is collar pruned all the new shoots must necessarily arise at ground level, and there cannot be any development of a new main stem. The old wood decays down from the top, and the bush becomes a cluster of stems arising from the shell of the old main stem. In the most favourable case the new stems produce roots, and ultimately, when the old stem has disappeared, the bush is replaced by a group of more or less independent single-stemmed plants, usually weak and unthrifty.

As far as is possible, cutting back the main stem of the bush should be avoided. It is sometimes necessary to do so in the treatment of stem diseases and branch canker, but it should not be done merely as a pruning operation. When all the branches arise from ground level, the danger of attack by *Rosellinia* is greatly increased, because of the accumulation of dead leaves in the base of the bush. Further, it is impossible to treat some stem diseases properly if there is no main stem to cut back on. This question deserves more attention than has yet been given it, especially as regards the first cutting back of young tea, for it is that which decides what the main stem of the bush is going to be.

On one estate in Ceylon, after bushes had been collar pruned, the new shoots grew to a height of about 18 inches and then died back. On examination it was found that the shoots were ringed at the base. The bark was blackened for a short distance, and then became friable and broke up into fragments. Meanwhile, a callus formed round the stem above the injury, as in the case of nursery plants ringed at the collar. The disease did not extend up the stem, but the shoot died because its water supply was cut off. Subsequently clusters of shoots developed round the base of the dead shoot.

A fungus, probably a *Rhizoctonia*, was found to be fairly common in the soil round the bush, whence it spread to and overran the bases of the stems. Treatment with a fungicide during the rains was ineffective. The shoots which developed subsequently during the dry weather were not attacked.

Collar Rot of Nursery Plants

One frequent cause of the death of seedlings is an injury to the stem just above ground level. The plants lose their leaves and die back from the top after attaining a height of 6 to 10 inches, and on examination the stem is found to be blackened for a length of half an inch or less from ground level upwards. The blackened region is usually thinner than the parts immediately above and below it; it may be only slightly depressed, or it may be bordered above and below by a swollen callus.

The stem is ringed over a limited area. This may prevent the ascent of water up the stem and so quickly cause the death of all the parts above the injury, in which case the blackened region is only slightly thinner than the remainder of the stem. In many instances, however, the injury is at first insufficient to cause the stoppage of the water supply, and the plant continues to live for some weeks, or even months. In the latter case, the part above the injury increases in thickness, using up the food manufactured by the leaves. But that food cannot descend past the injured portion, and consequently a swollen callus is formed at its upper edge. A similar, but smaller, callus is also formed at the lower edge of the affected region, owing to the increase in diameter of the root and the lower portion of the stem, which is able to continue its growth for a limited period at the expense of the food stored in the seed. Very frequently the lower part of the stem, below the injury, produces two new healthy shoots, thus showing that the root is not diseased.

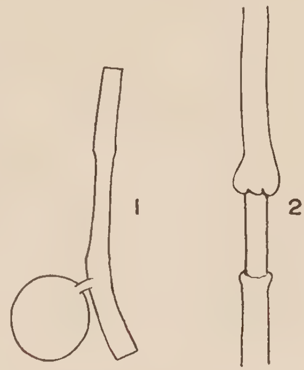

Fig. 43.—Collar Rot of nursery plants, natural size: 1, early stage; 2, advanced stage.

The condition described above has been noted in Java by Bernard, who states that it occurred in nurseries which were not shaded, and also on plants grown from seed at stake. He suggests that the fungus concerned (which was not identified) was introduced with the seed, as the disease

occurred on plants grown from imported seed, but not on plants grown from Java seed on the same estate. But, seeing that the plants are not attacked until they have attained a fair size, and that the attack is limited to a definite region well above the seed, that explanation would not appear feasible.

Bernard finds the primary cause in an overheating of the exposed soil by the sun, followed by excessive humidity. Owing to the heating of the soil the tissues of the stem at ground level were injured or made less resistant to fungus attack, and the subsequent humidity favoured the growth of the fungus. On both counts the fungus was the more easily able to attack the young plants. Bernard advises that affected nurseries should be shaded, and, if too wet, should be drained. To stop the growth of the fungus the beds should be watered with lime-water.

It has been proved in America that very young seedlings of *Pinus*, about an inch high, can be killed if the surface soil is overheated by the sun. In such cases the plant is injured at ground level, and the injury often occurs on one side of the plant only, viz. that which was most exposed to the sun. The injured seedlings soon die, and they do not develop a swollen callus.

Similar injuries have been noted in America on seedlings of spruce and Douglas fir, several months old, but in no case was any swelling found above the injured portion. Ringing of the stem, with the subsequent formation of a swollen callus above the injury, only occurs on older nursery stock, two to four years old, on which it is well known both in Europe and America; and in both continents it is attributed to excessive heating of the soil.

Hope and Carpenter have described the same condition from Assam, where it was observed in 1909. The plants began to turn black from the top of the shoot downwards, the leaves fell off, and only the blackened dead stem remained standing. But the roots were healthy, and some of the plants produced new shoots from below the injury. Many of the stems bore a swollen annular callus near the surface of the ground—*i.e.* above the original injury—and in some cases that had produced new rootlets. These authors did not discover any fungus in the dead stems. They attributed

the effect to mechanical injury of the stem caused by soil particles dashed against it by the heavy rains which prevailed at the time when this condition of the plants was first noticed.

The increase in thickness of the stem above the injury, and the occurrence of a swollen callus at the lower edge of the sound tissue, indicate that the injury occurred some considerable time before it was noticed. Where roots arise from the callus, that time must be still longer. Hence it is scarcely possible to explain this condition by reference to the weather at the time when it is observed.

On the other hand, the fact that the plants ultimately die, and that different stages of injury are found in close association at the same time, point to fungus action as the primary cause. Further evidence in favour of the latter explanation has been noted in Ceylon, viz. the disease occurs during the wet season; it occurs in patches through the nurseries, not all over the beds or attacking all the plants at the same time; in many cases the plants at the edge of the beds are not affected; when the first shoot has died, and two new shoots have been produced below the injury, these new shoots may be attacked in the same way.

The affected plants, in Ceylon, commonly bear minute white patches on the blackened constricted area. These are the fructifications of a *Fusarium*, which is probably the cause of the injury. That, however, has not yet been definitely proved.

It is probable that several fungi which occur in the soil can cause an injury of this kind, especially if the plants are unthrifty because of unfavourable soil conditions. It is surprising to note in how many cases the affected nurseries have been situated on the sites of old cooly lines or cooly gardens. In some instances that may to a great extent account for the presence of the disease, for it is in just such places that one would expect injurious soil fungi to be rampant. It is generally recognised in Ceylon that tea does not do well on the sites of old cooly lines, and that fact has been brought forward in support of the theory that tea will not endure lime, but it is more probable that the explanation is to be found in the existence of numerous soil fungi in such localities.

The dead plants should be uprooted and burnt, and the affected patches, and the plants immediately surrounding them, should be watered with a solution of Jeyes' fluid—1 oz. to a gallon of water.

Lichens and Mosses

As in the case of the majority of tropical trees and shrubs, the stems of the tea bush, when they are old and their increase in girth has slowed down to an almost imperceptible rate, become covered with lichens. This condition may set in at any time when the growth slackens—if, for example, the bushes are stunted through lack of food or through unfavourable conditions—but in the majority of cases it is the almost inevitable accompaniment of age. Bushes whose stems are covered with lichens are often said to be "hidebound"; but it must be borne in mind that the lichens are not the cause of the stoppage of growth, but the consequence of it.

The lichens which are found on the stems of the tea bush may be classified into two groups, viz. those which lie flat on the surface of the stem, and those which form leaf-like irregular sheets, attached at a few points and curling up at the edges. By far the majority of the tea stem lichens belong to the first class, and of these many are so thin that they appear to be merely stains on the bark, while few of them reach a thickness of a millimetre. White patches, uniting with one another, but sometimes separated by black margins, pink patches, or green patches, the latter usually thicker than the others, cover the old stems, all so closely attached to the bark that they appear to be part of it. When in fruit, irregular black lines, or minute black points, or yellow, cup-shaped bodies, appear on the coloured patches.

Lichens, in the majority of cases, are not parasitic, but epiphytic—that is, they live on the stem of the tea bush but do not derive any nourishment from it. There is some evidence that certain of the thicker species may kill the outer layers of the bark, but they do not penetrate into its inner tissues. Theoretically, they may cause some slight damage to a bark which is permanently green by depriving it of

light and air, but, in reality, the lichens of the tea bush do not cause any noticeable injury to the stems.

Leaf-like lichens are not common on tea stems and are only likely to occur in the wettest districts. They form irregular sheets, lobed at the edges, and usually more or less curled up, attached to the stem by hairs on the under surface. One species which is common at higher elevations in Ceylon is thin and tough, and white or yellowish in colour.

Other epiphytic growths on the stems of the tea bush include algæ, mosses, and ferns. Microscopic algæ are almost invariably present on tea stems, though they are not discernible to the naked eye ; but in very wet districts they may form a slimy green coat over the stems during the rains, disappearing, or drying to very thin green strands, in dry weather. Mosses and ferns need no description ; it is only in very humid districts that these are found in quantity on the stems of tea, and then, as a rule, only towards the base of the bush.

Though these epiphytic growths do not in themselves cause any appreciable injury to the tea bush, it is urged that they harbour insects which may do so. The insects take refuge under the lichens, or among the mosses, and are sheltered by them. A further objection is that they keep the stems moist and so favour the growth of fungi whose spores may happen to lodge among them. Both these arguments, however, can only refer to the leaf-like lichens, with the mosses and ferns ; they cannot apply to the flat, totally adherent lichens which are practically incorporated with the stem, for there is no space beneath those for an insect to lodge in. It is not worth while, therefore, to attempt to remove these flat lichens, which appear merely as stains or thin plates on the bark. The kinds to be removed are the leaf-like species which grow away from the stem.

In Ceylon it is customary, in some of the wetter districts, to scatter slaked lime over the bushes after pruning, to kill these epiphytic growths. In Northern India the use of alkaline washes or sprays is recommended after pruning. Such washes not only kill lichens and mosses, but they also destroy the eggs of insects. Failing any other method, they may be rubbed off.

Abnormalities of Stems

Fasciation

Fasciation is the term applied to the condition in which stems, instead of being normally round, are flattened and ribbed as though several were united side by side in a band. It is not a rare phenomenon in cultivated plants, but appears to be uncommon in the case of tea. An example of a fasciated green shoot of tea is shown in Fig. 44.

Fig. 44.—A fasciated tea stem. × ½.

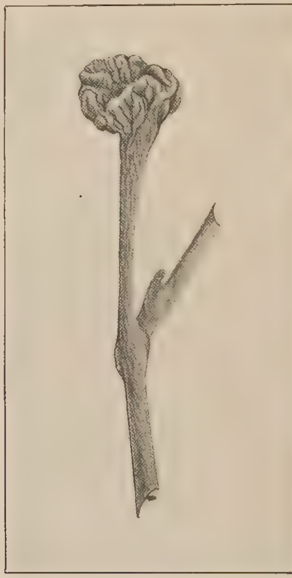

Fig. 45.—Gall on a plucked shoot. Natural size.

Fasciation in some instances is due to the attacks of insects or fungi, but in the majority of cases nothing definite can be stated, except that they are certainly not due to either of those causes. It does not appear to have been caused by either insects or fungi in the few cases observed on tea.

Galls on Plucked Shoots

A curious formation is illustrated in Fig. 45. In this case the plucked shoots have developed a top-shaped outgrowth at the apex, resembling an insect gall. No trace of insect action could be observed in these structures, and it would appear that they are to be classed merely among the abnormalities.

Burrs

Burrs are occasionally found on tea stems or branches, more especially on the main stems of large bushes. They

Fig. 46.—Burr on a tea stem. $\times \frac{1}{4}$.

are usually more or less hemispherical and project from one side of the stem, but on branches of medium size, about 2 inches in diameter, they may almost completely encircle the branch. The largest specimen hitherto observed was

about 5 inches in diameter. The surface of these burrs is generally irregularly nodular, and they resemble the burrs found at the base of elm trees, which are attributed to the suppressed growth of adventitious buds.

Abnormal Callus Outgrowths

In the normal process of wound healing, new wood and bark are produced at the edge of the wound and form a swollen edge known as a callus. Under favourable conditions the calluses from the edges of the wound ultimately meet and fuse together, thus effecting a complete healing.

Fig. 47.—Abnormal callus outgrowths. ×½.

In some instances, an abnormal outgrowth of callus has been observed on tea bushes, both from pruning cuts and from the edges of old wounds. These outgrowths are thin flat plates, which originate at the margin of the wound, and not only cover it but extend farther over the stem, sometimes almost completely surrounding the latter. They are thin at the margin, red-brown, concentrically zoned and variously lobed. In some cases new plates may arise on the old ones, so that the structure approaches a rosette formation.

When fresh, these plates are closely applied to the uninjured parts of the stem over which they extend, but they are not organically united to it. Consequently, when they dry they shrink away from the stem, except at the place from which they originated.

CHAPTER V

ROOT DISEASES

The existence of a root disease is, in general, only brought to the notice of the planter by the death of the bushes affected. When a fungus attacks the roots, it gradually destroys their tissues and renders them incapable of performing their normal functions, particularly that of supplying water to the parts above ground. In consequence, the leaves wither and fall off, and the branches dry up. But, except in rare cases, the fungus does not ascend into the stem and branches, save perhaps for a short distance above the collar.

In some instances, the whole bush appears to die suddenly, all the leaves turning a coppery brown and remaining on the branches for a few days. This often occurs in attacks of *Ustulina zonata*, even when the bush dies in wet weather. In other cases, as in attacks of *Fomes lignosus*, the leaves may fall off gradually for several months until the branches only bear a few, still green, towards the tips, and the bushes may remain in this condition for a long time before they finally succumb.

Bushes may be killed by stem diseases as well as by root diseases, and it is scarcely possible to decide to which class of disease the death of a bush is to be assigned until it has been dug up. Whenever bushes die, root disease should be suspected, and the bushes should be dug up and the roots examined to ascertain whether they show signs of decay or bear the mycelium of a fungus.

If a bush suddenly dries up as though it had been scorched and dies with all its leaves still attached, it is almost certainly a case of root disease. If the leaves are shed gradually, and the bush does not recover, root disease is again the most probable cause. But if after the fall of the leaves

new shoots are produced, then root disease is improbable. Further, if the branches die, but new shoots are produced at the collar, the cause is most probably in the stem, not in the root. Nor, as a rule, is the root affected if the bush dies branch by branch.

Bushes may, of course, die from other causes. Lightning is often responsible for the death of bushes in patches, especially in the neighbourhood of large boulders. Again, the gradual fall of leaves, with the consequent "thin" appearance of the bushes, may be produced by an insect attack,—by one of the mites, for example. Scarlet Mite (*Brevipalpus obovatus*) frequently causes a partial defoliation of the bushes, and, curiously enough, such bushes often occur in small patches, as in cases of root disease. But leaf-fall caused by Scarlet Mite may be identified by the blackish discoloration which extends from the leaf-stalk over the base of the leaf, and, with the aid of a lens, by the minute red insects present on the under surface of the discoloured areas.

In cases of root disease, there is, in general, a tendency for the bushes to die out in patches. This is to be explained by the gradual extension of the mycelium of the fungus underground in all directions, either from the bush first attacked or from the original source of infection. In some root diseases, *e.g.* those caused by *Rosellinia*, *Fomes lignosus*, and *Poria hypolateritia*, the mycelium can spread free through the soil, *i.e.* unattached to any dead or living plant tissues except at its point of origin; in others, *e.g.* those caused by *Ustulina zonata* and *Fomes lamaoensis* (Brown Root disease) the fungus only passes from one bush to the next when their roots are in contact. In either case, the bushes are killed in gradually widening circles.

The most usual point of origin of a root disease in tea is a dead stump, whether a stump of a jungle tree left when the land was cleared, or the stump of a shade tree which has been felled because it had grown too big. It is not possible to differentiate between stumps of different species of trees; apparently any stump is capable of serving as a host for some of the fungi which can attack the roots of the tea-bush. In Ceylon, the common root disease of young clearings is that caused by *Poria hypolateritia*, which appears in all cases

to originate on the jungle stumps. The danger of disease from this source is not past until the stumps have decayed, a process which may not be completed for many years. One case has been recorded in which Brown Root disease spread to tea from stumps of Na (*Mesua ferrea*) fourteen years old.

The cost of removing all jungle stumps from a new clearing is generally considered prohibitive, especially in the case of tea, where the value of one plant is relatively small. Moreover, though the decay of the stumps must be brought about by fungi of some kind, it is by no means inevitable that the fungi which develop on any given stump will be such as are parasitic on tea. In the majority of cases they will not be; and under the present methods of opening estates the planter accepts the risk. But he should fully recognise that he does so, and be prepared to carry out extensive operations against root diseases should they arise. New clearings should be carefully watched for any appearance of root disease round decaying stumps, and all cases should be dealt with promptly and thoroughly. The jungle stump responsible must be completely extracted and burnt, and the patch isolated and limed. It is worth while to devote extra care and attention to root diseases in new clearings, and so avoid the necessity of periodical treatment when the tea is mature.

In old tea, the chief source of root disease lies in the stumps of shade trees which have been felled. *Grevillea robusta* is a notorious offender in this respect, and its stumps very frequently give rise to *Ustulina*, or, more rarely, to Brown Root disease. When Grevilleas have to be got rid of, their stumps should be dug out. Jak (*Artocarpus integrifolia*) and Dadap (*Erythrina lithosperma*) have been found to serve as a starting-point for *Fomes lignosus*. *Albizzia moluccana* is one of the most difficult shade trees to deal with in connection with root diseases, and one is inclined to recommend that it should never be planted through tea. Owing to its rapid growth, it usually gets out of hand in a few years, and, in certain of the low-country districts of Ceylon, trees with trunks 4 feet in diameter were formerly not uncommon in tea. When cut down, its stumps very generally afford a place of origin for *Ustulina*, *Diplodia*, and *Poria*, and large numbers of bushes are killed out round

them. With regard to these common shade, or green manure, trees of tea, it might almost be said that from their stumps root disease is the rule rather than the exception.

Seventeen root diseases have now been recorded as attacking tea. The following particulars may assist in distinguishing between them, if the roots are examined as soon as the bush is dead:

External Appearance of the Root

Smooth and apparently sound	*Botryodiplodia.*
Longitudinally split	*Armillaria.*
Rough with minute black and white cushions	*Ustulina.*
Rough with encrusting sand and stones:	
General appearance black and white	*Poria.*
With brown mycelium intermixed	*Fomes lamaoensis.*
Embedded in a cement-like block	*Polyporus mesotalpae.*
Covered with cobwebby grey mycelium	*Rosellinia.*
Covered with cords of mycelium:	
Cords red to black, tough	*Poria; Armillaria.*
Cords white, flat, membranous	*Irpex subvinosus.*
Cords white, rounded, rather loose	*Polyporus interruptus.*
Cords white, tough	*Fomes lucidus.*
Cords yellowish white, tough	*Fomes lignosus.*
Cords black, woolly	*Rosellinia.*

Appearance after Removal of the Bark

Red strands between bark and wood	*Sphaerostilbe.*
White fans of mycelium	*Ustulina.*
A continuous white layer of mycelium	*Armillaria.*
Small white stars	*Rosellinia arcuata.*
Coarse white or black stars	*Rosellinia* (Northern India).
Short irregular black strands	*Rosellinia bunodes.*
Thick masses of white mycelium irregularly arranged	*Fomes lucidus.*
Scattered patches of brownish-white mycelium	*Fomes applanatus.*

Internal Appearance of the Wood

Mottled	*Fomes applanatus.*
Brown veins	*Fomes lamaoensis.*
Black veins	*Ustulina.*
Short black lines, radial and longitudinal	*Rosellinia bunodes.*
Red veins or sheets	*Poria.*
Uniformly blackish grey: hard	*Botryodiplodia.*
Uniformly dark slate; soft	*Polyporus mesotalpae.*

Treatment of Root Diseases

The treatment of root diseases involves three factors, viz. isolation of the affected area, removal and destruction by fire of dead bushes and decaying stumps within the area, and disinfection of the soil by means of lime.

Isolation of the affected area is necessary in order to limit the spread of the fungus underground. It is essential in the majority of cases of tea root disease, the only exception being that caused by *Diplodia*. The area should be surrounded by a trench, from eighteen inches to two feet in width and depth : it must be deep enough to get below the lateral roots of the bush and below the level at which the fungus normally travels. The earth excavated in making the trench must be thrown inwards towards the centre of the patch ; because of this, it is perhaps preferable to dig out and burn the dead bushes, etc. before making the trench, otherwise there is a danger that pieces of the diseased roots may be overlooked.

The trench must be dug so as to enclose a circle of bushes which appear to be healthy. Neglect of this precaution—and it is often neglected because it is thought to involve an unnecessary waste of bushes—usually entails a repetition of the treatment a few months later, for the simple reason that the mycelium has generally travelled beyond the dead bushes and is already attacking the next row, before the disease is discovered. An alternative method is to dig two trenches, one surrounding the dead bushes, and another, outside that, enclosing a ring of apparently healthy bushes.

The dead bushes should be dug up, and burnt on the spot if possible. All pieces of diseased roots must be collected and burnt. Any dead jungle stump in the disease patch must also be dug up and burnt, its lateral roots being followed up and extracted as far as possible. This operation should be supervised most carefully. The cooly no more understands why he is doing it than he understands why drinking water should be boiled or filtered ; and if left alone, he will not dig out all the roots, or will throw them among the surrounding tea.

Lime should be forked in over the affected patch. Any diseased roots which are turned up during the forking

should be collected. Lime may kill fungus threads in the soil, and it hinders or prevents the growth of fungi by making the soil more alkaline and thereby inducing conditions unfavourable to them, but it cannot have much effect on the fungus threads inside pieces of wood. As to the quantity of lime to be applied, it must be clearly understood that the amount generally considered permissible in manuring tea is of little use in the treatment of root diseases. Such work has been severely handicapped by the almost universal belief that tea will not endure any reasonable quantity of lime,—a belief which does not appear to be supported by any published results of experiments. About five hundred pounds per acre is considered the limit; but, on the other hand, in combating a serious attack of *Botryodiplodia* on old tea in a low-country district in Ceylon, four pounds per bush has been applied over a large area without detriment to the bushes. In treating root diseases in old tea, the quantity should be at least four pounds for every bush or vacancy within the isolated area. In dealing with plants one or two years old about two pounds per bush should be allowed. Tree stumps require more, up to sixty pounds for each dead stump, according to the size of the stump.

It is seldom worth while to replant root disease patches within a year of treatment. In the interval, the ground should be clean weeded, and forked over two or three times. The spot should be inspected periodically and any bushes which have died since the treatment removed and burnt.

The following treatment for root diseases was recommended by Raciborski in Java in 1899. After the dead bush has been dug up, and all its roots extracted and burnt, lime is forked in over the affected patch. It is then watered with a solution of ammonium sulphate, containing 1 lb. of ammonium sulphate per gallon. The rationale of the treatment is based on the interaction of the lime and the ammonium sulphate. When these two chemicals are brought together, the lime is converted into calcium sulphate and ammonia is liberated. The lime is put completely out of action as a fungicide, but it is claimed that the ammonia, in a gaseous form, penetrates the interspaces of the soil and renders the fungus harmless.

The efficacy of the foregoing treatment would seem very

problematic. Ammonia scarcely possesses such powerful fungicidal properties as are postulated. It is said to have been employed successfully in cases of Brown Root disease in Northern India, 2 lb. of lime and 1 gallon of the solution being used for each vacancy. It is also claimed that the ground so treated may be replanted with safety a month later. Against that we have the fact that in Brown Root disease, the fungus, as a rule, is practically entirely extracted with the dead bush, and in one instance a plant supplied immediately after the removal of a dead bush was not attacked by the disease. With the quantities stated above, three-quarters of the lime is left unchanged, and the reported good effect of the treatment may have been due to that.

Rosellinia

(*Rosellinia arcuata* Petch)

Rosellinia is perhaps the best-known name in connection with root diseases of tea in Ceylon, but, in reality, this disease is of comparatively rare occurrence. It was the first fungus to be identified as the cause of a root disease of tea in that country, and the name was subsequently applied to all cases of tea root disease. It is, however, certainly less common there than Brown Root disease, *Poria hypolateritia*, or *Ustulina*, and it has rarely been found in the low country. The common *Rosellinia* in Ceylon is *Rosellinia arcuata*, which occurs also as a root disease of tea in India and Java.

The disease may be identified fairly easily from the appearance of the affected roots. These are covered with black strands of mycelium, more or less woolly in appearance, which usually run longitudinally along the root, and sometimes unite to form a network: and if the bark of the root is taken off carefully, white stars of mycelium will be found between the bark and the wood.

With the aid of a microscope, it is always possible to identify a tea root disease caused by *Rosellinia* from the mycelium alone. In the species of *Rosellinia* parasitic on tea, the hyphae, especially the darker hyphae on the exterior of the strands, bear pear-shaped swellings. These occur

at one end of the sections into which the hyphae are divided by the septa, and as the inflated end of one section joins on to the narrow end of the next, the structure reminds one of an old-fashioned condenser (Fig. 1). As a rule, these swellings do not occur before every septum.

The most remarkable feature of *Rosellinia arcuata* is the extraordinarily rapid spread of its mycelium. This usually

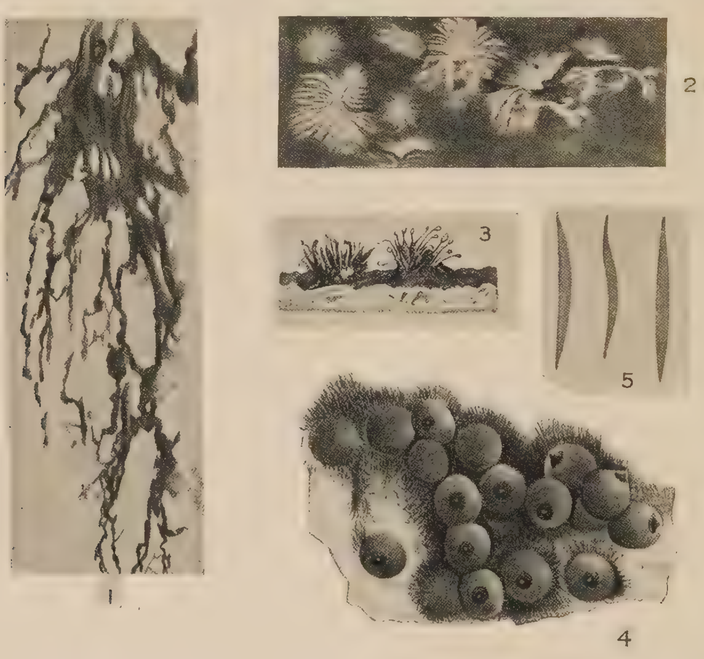

FIG. 48.—*Rosellinia arcuata.* 1, Mycelium on the exterior of a root, natural size; 2, stars of mycelium between the wood and the bark, natural size; 3, conidiophores, × 4; 4, a group of perithecia, × 4; 5, ascospores, × 500.

travels in the top two or three inches of the soil. It prefers soil which contains a large proportion of dead leaves, etc., and if the ground is covered with a thick layer of dead leaves it runs along the surface of the soil under and among them. That point must be especially borne in mind in attempting to eradicate it. The mycelium consists of somewhat fleecy strands and sheets, at first white, then smoky grey, and finally black. The change in colour may be noted by following the mycelium back to its starting-point. The advancing, rapidly growing portion is white; behind that comes a

region in which the mycelium is changing colour and has become grey; finally, towards the point of origin, the mycelium is mature and black, and, if on dead wood, it may have begun to produce spores.

When the mycelium reaches a tea bush it travels down the root, and for a short distance up the stem. When the bush is first attacked, the mycelium forms a loose, cobwebby mass round the tap root, and stretches across to the lateral roots in similar loose masses. This is well seen on young tea plants, which die soon after they are attacked. On older tea bushes, it soon forms black strands closely applied to the root. From the apparent difference in habit in the two cases, it was at first supposed that these represented two species of *Rosellinia*, but by developing the fructification in each case it has been proved that the loose and the compact mycelia are only forms of the same fungus.

The mycelium on the exterior of the root gives off branches which penetrate the bark, and ramify between the bark and the wood. At each point of entry, it divides into a number of strands which radiate over the surface of the wood and form a white star, up to half an inch in diameter. These stars are readily seen if the bark of a diseased root is carefully taken off, and they afford one of the easiest means of identifying the disease (Fig. 48).

While the underground mycelium is permeating and killing the roots, that above ground grows up along the stem, where it forms a continuous sheet, purple-grey at first, and then black. This sheet usually extends all round the stem, and to a height of about six inches above the soil. Here the fungus passes through a stage which was entirely overlooked in the first investigation of *Rosellinia* in Ceylon; and as that is by far the most important stage, the oversight may account for any lack of success in treating *Rosellinia*. Emphasis was laid on the fact that the fructification of *Rosellinia* was rarely found, and therefore its extension must be brought about by the spread of the mycelium. But *Rosellinia arcuata* has at least two kinds of fructification, a conidial stage and perithecial stage; and while the perithecia are rare and scarcely ever found on the tea bush in the field, the conidial stage occurs on almost every tea bush attacked. The spread of the fungus in any given patch is no doubt due to the extension

of the mycelium, but its spread to other parts of the field is brought about by the distribution of the conidia by the wind or by other agencies.

The conidia, the first kind of spore, are borne on short, erect, bristle-like stalks. These stalks are produced in clusters (Fig. 48) on the sheet of mycelium on the stem, and since they arise close together, the sheet becomes velvety in appearance. Each stalk divides into numerous branches at the apex, and these branches bear the conidia. The latter are white or greyish in mass, and form a whitish powder over the black mycelium; they are readily detached, and consequently can be blown away by the wind or transferred from place to place on the clothing of coolies.

After the bush has been dead for a long time, the second form of fructification, the perithecium, appears. The perithecia are minute black spherical bodies, about one-tenth of an inch in diameter (Fig. 48). They occur clustered in groups on the sheet of mycelium on the stem, among the remains of the stalks which bore the conidia. Each perithecium contains numerous asci, in which the second type of spore is produced. These spores, the ascospores, are black, narrow-oval, with pointed ends. Practically, these ascospores are a negligible factor in dealing with the disease in tea, because the dead bushes are seldom left standing long enough to produce them.

A curious effect, caused by *Rosellinia*, is sometimes seen on bushes which are attacked towards the close of the monsoon. The appearance of the stems suggests that they have been gnawed all round by some animal, but examination shows that the dead bark is still intact, while the occurrence on it of the typical threads of *Rosellinia* definitely indicates the cause. Apparently, the advancing mycelium surrounds the stems at the surface of the soil and kills off the bark all round for a length of three or four inches. When fine weather ensues, the youngest mycelium in the soil dies, and provided that it has not got a sufficient hold of the stem to enable it to withstand the drought and live there independently, the mycelium on the stem dies also. The bush is therefore girdled or ringed at the collar, but, tea being a hardy plant, that does not kill it. The result of the ringing is that the food elaborated by the leaves cannot pass down

to the roots, but is arrested by the circle of dead bark; consequently a swollen ring of tissue (callus) is formed round the stem above the dead patch and a similar ring below the latter. It is possible that this effect is also produced when bushes in the early stages of the disease are pruned, owing to the removal of the shade and the consequent action of sunlight on the mycelium.

Patches of tea killed by *Rosellinia* are occasionally found in the neighbourhood of *Grevillea* stumps, but the root disease commonly associated with these stumps is that caused by *Ustulina zonata*. In several cases, where an attack of *Rosellinia* has been watched from an early stage, it has been found to originate in accumulations of dead leaves. In one case, the leaves which had drifted into the bottom of a *Panax* hedge afforded it a starting-point from which it spread between three and four yards in three weeks. In another case, a mango tree was felled and the log left lying in the tea; in the course of time, dead leaves accumulated on one side of the log, and from these *Rosellinia* spread to the tea. Its occurrence round *Grevillea* stumps may be explained in the same way.

Fig. 49.—Injury caused by *Rosellinia* on the main stem of a tea bush. × ½.

Rosellinia arcuata occurs in up-country jungles in Ceylon, where it is known to kill species of *Strobilanthes*.

In the treatment of *Rosellinia* two points must be borne in mind: first, that the disease may be conveyed to other spots by spores (conidia), which occur in abundance on almost every dead bush; and, secondly, that the upper layers of the soil around the dead bushes are permeated by mycelium,

which has doubtless advanced beyond the bushes which show visible signs of being affected.

In order to prevent the dissemination of spores during the uprooting and removal of dead bushes, straw or dry rubbish should first of all be heaped round the main stem and over the lower branches, and set on fire, so as to destroy these spores as far as possible. If this is not done, the spores on the stem will be scattered when the bush is pulled up, and will also be conveyed elsewhere on the clothes and feet of the coolies, as well as on the tools used. After this preliminary scorching, the dead bushes must be dug up and burnt. Burning must be done on the spot if possible—it is always possible if three or four bushes have been killed,—and it is cheaper in the end to spend a little on kerosene than to wait weeks for the bushes to dry. During the drying period they may produce myriads of spores, especially if the preliminary scorching has been omitted.

To prevent the farther spread of the mycelium, a trench a foot in depth must be dug round the affected spot. It must be dug so as to surround not only the dead and dying bushes, but also a complete ring of apparently healthy bushes. There is no doubt that some of the surrounding bushes will already have been attacked, even though they do not show any evident signs of disease. The living bushes enclosed by the trench should be heavily pruned, as well as a circle of bushes immediately surrounding the trench. This pruning will let in sunlight to kill the mycelium which may have just reached these bushes. Before the trench is dug, all dead leaves and prunings must be raked into the centre and burnt with the dead bushes. In dealing with *Rosellinia* the surface of the soil must be made as bare as a tennis court. A layer of dead leaves and twigs will protect the mycelium and provide it with food, and thus neutralise all attempts to get rid of it. After the trench is dug, it must be periodically inspected and cleaned out; if it is allowed to fill up with dead leaves, it is worse than useless.

Lime should be forked in over the affected patch, and scattered in the trench. Quicklime is best for forking in the bare soil, but air-slaked lime should be scattered over the stems of the pruned bushes. It is better to lime the patch before digging the trench.

Needless to say, prunings must not be buried in fields attacked by *Rosellinia*; that is just what the fungus requires. Several instances of the occurrence of *Rosellinia* on buried prunings have been recorded, even after burial with sulphate of potash and basic slag. In one instance where the prunings were buried with sulphate of potash and basic slag, *Rosellinia* was found on them four months later.

Green manure plants should not be grown on *Rosellinia* patches, as they provide shade which favours the development of the mycelium. It is almost impossible to eradicate *Rosellinia* under dense shade. If the shade is permanent the trees should be lopped, and in all cases the shade should be removed as much as possible.

It is generally a waste of time to replant patches infected with *Rosellinia* within eighteen months of the time of treatment.

Rosellinia arcuata has been found to attack, in addition to tea, *Panax*, *Strobilanthes*, camphor, *Tephrosia candida*, and dadap.

Rosellinia bunodes (B. and Br.) Sacc.

This species attacks tea in Ceylon, India, and Java, though it appears to be rare in the first-named country. It has also been found to kill *Hibiscus*.

The general appearance of the mycelium on the exterior of the roots is the same as that of *Rosellinia arcuata*. When the bark is removed, however, the appearance of the surface of the wood is found to be different; small black points and short, straight or curved, black strands are found on, or embedded in, the wood, while a careful examination will show similar strands permeating the bark. The strands on the wood may be greyish white when fresh, but they soon turn black. In general, they are about four millimetres long and a third of a millimetre broad. If a diseased root is split, fine black lines running radially towards the centre are seen in the wood, often with others running irregularly down the root. When sawn across, the wood shows similar radial lines, and sometimes a continuous black line forming an irregular circle a little distance from the exterior.

The description of the action of *Rosellinia arcuata* applies,

in general, to the present species also. One effect, however, which does sometimes occur in cases of *Rosellinia arcuata*, appears to be more common in cases of *Rosellinia bunodes*. This is the death of a single branch in a bush which otherwise appears quite healthy. It usually happens in bushes which have been collar-pruned, or pruned low down, and consequently consist of a number of small stems all arising

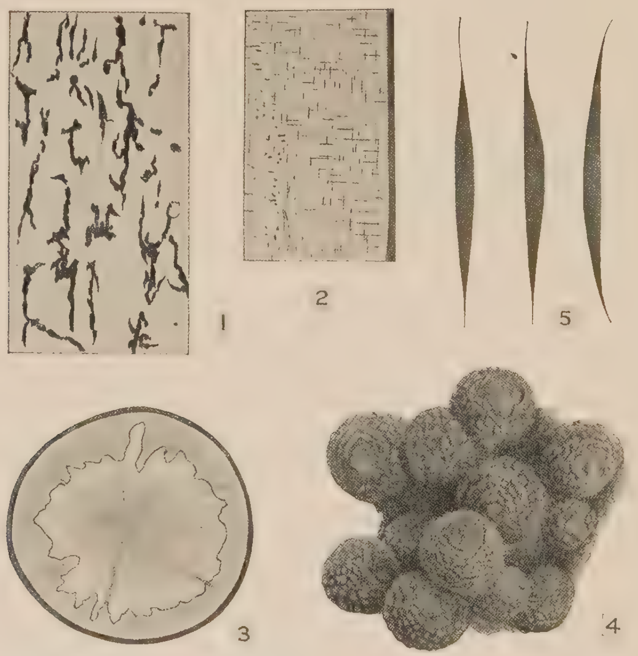

FIG. 50.—*Rosellinia bunodes*. 1, Mycelium on the wood of the root, natural size; 2, black lines in the root, longitudinal section, natural size; 3, cross-section of a root showing the black ring, natural size; 4, a cluster of perithecia, ×6; 5, ascospores, ×400.

from about ground level. The branch, as a rule, dies in the dry weather. On examination, a length of three inches or so at the base is found to be covered with the black strands of mycelium, and this part is thinner than the upper part of the stem and is bordered by a swollen callus. From this it is evident that the upper part continued to grow for some time after the base was attacked, and only died when the supply of water was completely cut off. Further examination of the bush will generally reveal black mycelium on the

stem and on one or more roots just below the dead branch; consequently the rest of the bush may be expected to die in course of time.

Observations in Ceylon, though perhaps not yet sufficiently numerous to admit of generalisation, would appear to indicate that this *Rosellinia* is less rapid in its development than *Rosellinia arcuata*, and that, in bushes such as those referred to in the preceding paragraph, it may develop on the individual bush among dead leaves which have collected in the base.

The fructifications (perithecia) of *Rosellinia bunodes* resemble those of *Rosellinia arcuata*, but are covered with minute warts. They are frequently found on the dead stems in the field.

The treatment of this disease should follow the same general lines as that of *Rosellinia arcuata*, but, where only one branch has died, the bush may be saved for some time longer by cutting off the dead branch, at its junction with the main stem, and scattering lime round, and in among, the stems of the bush. Dead leaves should be cleared out of the bases of the surrounding bushes.

Rosellinia sp.

Another *Rosellinia* which causes root disease of tea has been recorded from Northern India. In this case, when the bark of the root is peeled off, thick broad strands are found, which radiate, a few together, from centres, "like the arms of a starfish." These strands are white at first, becoming violet-black when old. The appearance described is quite different from that which is seen in cases of *Rosellinia bunodes* and *Rosellinia arcuata*, but the species which causes it has not been identified.

Ustulina zonata Lév.

This is the commonest root disease of tea in Ceylon, and it is in a great measure preventible. Its prevalence is due to the practice of growing *Grevillea* for shade or as a windbreak among tea, and cutting it out either for firewood, or when it has grown too big, leaving the stump to decay *in*

situ. It is not uncommon to see three or four dead tea bushes round each *Grevillea* stump over a large area. A similar source of this disease has arisen more recently through the felling of *Albizzia moluccana*, which has been planted through tea, for shade or for green manuring, and in some cases has been allowed to grow to an enormous size. When the trees are felled at or about ground level, the fungus grows on the dead stumps and spreads along their lateral roots to any tea roots which happen to be in contact with them. Lunumidella (*Melia dubia*) acts in the same way, but infection from this source is not common, as this tree is rarely planted among tea.

FIG. 51.—Tea bush attacked by *Ustulina zonata*, showing fans of mycelium between the bark and the wood. $\times \frac{1}{2}$.

In one instance, where the disease, in general, occurred round *Grevillea* stumps, several cases were noted which could not be associated with the stumps. This tea had been collar pruned, and from the character of the attack, it appeared that in these exceptional cases the bushes had been infected *via* the pruning cut by spores which might have been derived from the *Grevillea* stumps or from dead tea bushes.

When the disease is first noticed, the *Grevillea* or *Albizzia* stump is usually in the last stages of decay, and two or three of the surrounding bushes are dead. In some cases a regular line of dead bushes follows the course of a lateral root. The fructification of the fungus is then, as a rule, well developed at the base of the stump, and is extruding spores which will infect other stumps. Generally, the bushes die gradually,

that is, they become thin owing to the gradual fall of the leaves, but sometimes they dry up suddenly with all their leaves attached, and this may occur even in wet weather.

The dead roots do not bear any external mycelium. There are a few scattered, small, black spots here and there, but these are not conspicuous; they mark places where the internal mycelium has emerged through the bark to form

FIG. 52.—*Ustulina zonata*; fructification developing on the stem of a tea bush. × $\frac{3}{4}$.

a fructification, but has been arrested because it was not above ground. If the bark is removed, white, or brownish-white, fan-shaped patches of mycelium are found overlying the wood; these are frequently fused into a continuous sheet, but in all cases the fan structure is fairly evident. When the mycelium meets a crack in the bark and is thereby exposed, it develops a black edge. The wood of the root is usually permeated by black sheets which appear as black lines when it is cut.

The fructification is produced in abundance on the dead *Grevillea* or *Albizzia* stumps, and is generally present on tea bushes which have been killed by this disease. The mycelium emerges through the bark and spreads out over the surface of the stem, forming a white plate, up to two inches in diameter, and about one-tenth of an inch thick. On the surface of this plate, conidia, *i.e.* free spores, are produced. Frequently several plates arise close together and fuse into a continuous sheet. In dry weather, the growth of the plate is arrested, and hence it becomes concentrically furrowed, each furrow marking a temporary stoppage of growth.

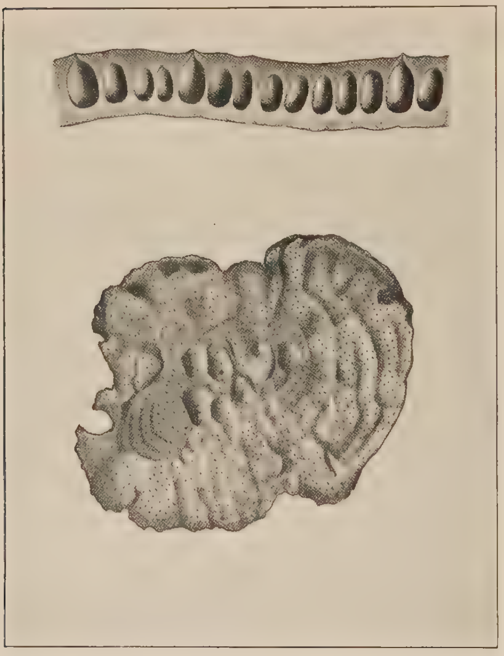

FIG. 53.—*Ustulina zonata.* Lower figure, the fructification, natural size; upper figure, cross-section of the fructification, showing the perithecial cavities. ×6.

In the stage described above, the plate is soft; but after the conidia have been shed, it changes completely in colour and consistency. It becomes greenish, then purple-grey, dotted with black spots, and when old and weathered is quite black. In these later stages it is hard and brittle. The black dots are the openings of the perithecia, in which the second kind of spore, the ascospores, are produced. If the fructification is broken across when in the purple-grey stage, these perithecia will be seen, embedded in the white internal tissue, but when the fungus is old it is black throughout and they cannot then be distinguished so easily.

The foregoing description refers to the typical form of the fungus, but *Ustulina zonata* is one of the most protean

of tropical fungi. The plates are frequently undulating and thrown into contorted masses, especially when they grow over the loose bark and earth at the base of a *Grevillea* stump. Sometimes they are stalked instead of lying flat on the stem, and frequently a number of stalks arise close together, each bearing a small plate at its apex. In sheltered situations, the upper surface may remain permanently white, even in the second stage.

Ustulina zonata was first found on coconut, but whether it was parasitic or not is not known. It has not been found as a parasite on coconut in recent times, though it has occurred on dead coconut stems. It is a common fungus in up-country jungles in Ceylon, and probably kills many native trees. In addition to tea, it is known to attack *Hevea*, pumelo (*Citrus decumana*), *Casuarina*, Lunumidella, *Cassia javanica*, Halmilla (*Berrya Ammonilla*), *Derris*, etc.

Ustulina usually attacks tea by spreading to its roots from the roots of decaying stumps. The fungus does not spread free through the soil, but only passes from the roots of the stump to those of the tea bush when the two are in contact. Consequently trenching might possibly be dispensed with in the case of this disease, but it is better to err on the safe side and to trench. The dead bushes, and the stump on which the disease originated, must be dug up and burnt, and lime forked in over the affected patch.

But the chief measures called for in this case are preventive measures. So long as *Grevillea* and *Albizzia* trees are cut down, the disease is certain to occur. Therefore, if it is desired to avoid it, that practice must be changed. On some estates, it has been found possible to pollard the Grevilleas at a height of about ten feet without killing them. In other districts in Ceylon they are said to die when pollarded, and in that case they should be uprooted, not felled, when it is desired to get rid of them.

With Albizzias the conditions are in many cases quite different. As a rule, they do not endure pollarding: when young *Albizzia moluccana* are pollarded, they are frequently killed back by *Botryodiplodia Theobromae* and become centres of this latter root disease. And in far too many cases, the Albizzias have grown so enormous, that extraction of their stumps is almost out of the question. One can

only suggest that when old Albizzias are felled, a trench should be dug round the stump, cutting through all the lateral roots. This might prevent the subsequent spread of *Ustulina* to the tea roots. Young Albizzias may of course be uprooted ; and now that the evils of felling Albizzias in tea are patent, the trees should not be left until they have grown to an unmanageable size.

Sphaerostilbe repens B. and Br.

This fungus, which has for some years been known to cause root disease in several cultivated plants, more especially *Hevea*, has recently been found by Tunstall to cause root disease in tea in India.

The affected bushes were supposed to have been killed by a water-logged condition of the soil, and further investigation showed that the disease was frequent on unhealthy bushes growing on acid, stiff, badly drained soils. The roots of the bushes have a water-logged appearance, and a peculiar smell " something like vinegar." The bark is a violet colour, and under the bark thick strands of mycelium radiate in star-fashion over the wood. Tunstall describes the strands as orange when young, changing to a pinkish purple later.

In general, the strands or cords (rhizomorphs) of *Sphaerostilbe repens* are stout flattened ribbons, red-brown and smooth on the surface and white and fibrillose internally. They run between the bark and the wood, and, when the bark is stripped off, it frequently happens that the strands split, the upper half adhering to the bark and the lower to the wood. They then appear white, sometimes, especially in the broader strands, with a fern-like arrangement of the hyphae. When old, the outer surface turns black.

Tunstall states that the attack usually originates from the stump of a tree, frequently a jak (*Artocarpus integrifolia*), and the fungus spreads from it through the soil from bush to bush. The thick strands of mycelium are able to grow through the soil like roots. " The disease is not always fatal. The condition of the soil is the determining factor. If the soil conditions are improved the bushes frequently recover, and as the attack is slow the condition can be determined and remedied before the bushes die."

The treatment which has been found successful is as follows: The patch of sickly bushes is surrounded by a trench deep enough to isolate the roots of the diseased

Fig. 54.—*Sphaerostilbe repens*; mycelium on the wood of a *Hevea* root.

bushes from those of healthy ones, and the soil is opened up by trenches between each row of bushes, mixing slaked lime with the soil at the rate of 4 lbs. per square yard.

This fungus has two kinds of fructification. The commoner

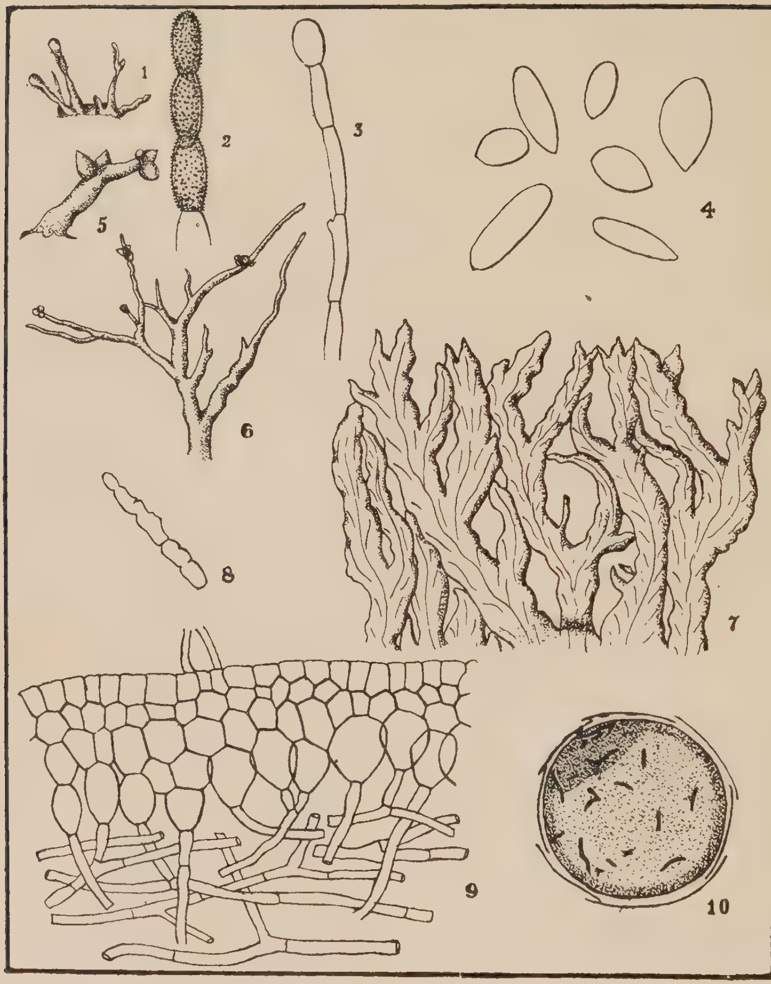

FIG. 55.—*Sphaerostilbe repens*; details of the fungus.

No. 1. A group of conidiophores. × 2.
No. 2. Tip of a hair from the stalk. × 350.
No. 3. Conidiiferous hypha from the apex of the conidiophores. × 500.
No. 4. Conidia. × 600.
No. 5. Perithecia on an old conidiophore. × 6.
No. 6. Groups of perithecia on a horizontal rhizomorph. × 2.
No. 7. Rhizomorphs from dadap.
No. 8. Cross-section of a rhizomorph; outline only. × 2.
No. 9. Cross-section of the cortex of a rhizomorph, magnified.
No. 10. Cross-section through the rhizome of arrowroot attacked by *Sphaerostilbe*; the dark lines are the sections of the rhizomorphs.

form consists of clusters of short red stalks with white heads of conidia. The second form is rarer, and consists of minute, dark red, flask-shaped perithecia, which are situated at the bases of the stalks, or along the stalks, or wherever the rhizomorphs are exposed. The fructifications are usually produced at the collar of the bush.

Diplodia

(*Botryodiplodia Theobromae* Pat.)

In its most common form, this root disease only comes into prominence after pruning. Sometimes the pruned bushes, which may have appeared perfectly healthy before pruning, fail to produce any new shoots and die off completely. In other cases, the green shoots grow to a length of about six or eight inches, and then begin to die. Their leaves become mottled with yellow, and then turn black, the latter change occurring first at the tip, or along the edges, and ultimately extending over the whole leaf. The fungus of Rim Blight (*Cladosporium*) often attacks the leaves at this stage. Finally the leaves fall and the whole shoot becomes dead and black down to its base. This condition may begin on one or more of the main branches, and gradually extend over the whole bush, or it may remain confined to one branch. In the former case the whole bush dies, in the latter only the branch affected; and all intermediate stages may be found. The disease usually appears from six weeks to three months after pruning.

The roots of a dead bush do not bear any external mycelium. Generally they are quite clean and smooth, but in some cases the bark is rough and abnormally thickened. If a bush is dug up as soon as the green shoots begin to die, the bark of the root will be found to be healthy, as a rule, and of a normal red colour internally; but if the bush is quite dead, the bark will be found to be blackened throughout, and the wood is also blackened. This discoloration is caused by the mycelium of the fungus, which permeates both the bark and the wood; but as it runs within the cells of the plant it is not visible to the naked eye. There is no evident mycelium between the bark and the wood. When

the bark is removed, the surface of the wood is seen to be a dirty brown, or blackish brown, but there are no strands or sheets of mycelium.

The fructifications of the fungus are minute black spherical bodies (pycnidia) which are embedded in the bark. They are not visible from the exterior, but if the bark is shaved lightly, the spheres are cut across and appear as black circles with a white centre. Each sphere contains a number of spores, which are white in mass when immature, but black when ripe. These spores are extruded in large numbers when the fructifications are ripe; and if a diseased root is kept for two or three days, even if lying exposed on a verandah, it becomes covered with a black powder which consists of innumerable spores. The spores are oval and divided into two parts by a wall across the middle—the typical *Diplodia* spore (Fig. 3). In some cases the immature spores are extruded and the powder is then white. In others, small black cushions of hyphae or spores burst through the bark, each surrounded by a narrow white fringe; very minute hyaline spores are produced on this white fringe. The latter appearance is often seen on the roots when bushes which have been dead for a few weeks are dug up.

FIG. 56.—Tea root attacked by *Botryodiplodia Theobromae*, showing black heaps of spores surrounded by a white fringe. $\times \frac{1}{2}$.

When bushes are examined in an early stage of the disease, as indicated by the yellow mottling of the leaves, the fungus is often found only in the finer rootlets. Such

bushes may recover, especially if treated with lime. But bushes which have died without putting out new shoots have their roots completely permeated by the mycelium of the fungus, though only a short time may have elapsed since the pruning. This would indicate a rapid growth of the fungus under the conditions induced by pruning. Attack *via* the finer rootlets is not universal; cases have been observed in which the tap root has undoubtedly been attacked first.

If untreated, the number of bushes attacked increases with each successive pruning. At first, perhaps only a few bushes die and little notice is taken of it; at the next pruning, the number is greater and attracts some attention; and the increase continues with each pruning until 50 per cent of the bushes may be attacked. Four prunings may convert indifference into panic.

The recognition of this disease in Ceylon is of comparatively recent date, but the number of recorded cases is steadily increasing, and, as a rule, the number of bushes killed in each case is greater than in any other root disease. Patches of from forty to one hundred dead bushes are not uncommon, and in one instance more than 10 per cent of the bushes were killed over an area of fifteen acres, leaving large bare spaces. Several correspondents estimate their loss at 25 to 50 per cent over some fields. The same disease occurs in Southern India, and is responsible for equally large losses there. In one case, on a field of twenty acres, seven thousand dead bushes were dug out in a month, and many more appeared to be in a moribund condition three months later.

Watt and Mann recorded what is probably the same disease from Assam, under the name of *Diplodia vasinfecta*. They stated that there was little to be seen on the surface of the diseased roots. The leaves assumed a yellow appearance, in which the network of veins was very prominently seen; they then began to fall off gradually, and the bush died branch by branch. The fructification was said to be very rarely found—a statement which is true only if the bushes are examined as soon as they die; as the bushes dry up the spores are produced in myriads.

In Ceylon, this disease is commonest on old tea, but it is by no means confined to that. Several cases have occurred

on tea after the first pruning, and, on badly affected estates, it has killed out nursery plants. In patches where bushes have been killed by this disease, supplies have been attacked. Watt and Mann record that in one case it was calculated that thirty acres of plants in a four-year-old garden had died, and in another even more had been destroyed. In Ceylon, it is chiefly a low-country disease, but cases have occurred at higher elevations.

In Northern India, young tea is said to be most frequently attacked when it has been planted on cleared grass land. It has been suggested that the wild sugar canes which abound on grass land there are responsible for that, as the fungus is a common one on sugar cane. On the other hand, the worst case recorded from Southern India was on tea on land previously virgin jungle, and it is not possible to associate the disease with any particular type of land in Ceylon. Tea on poor soil appears to be more liable to attack.

In the case of old tea, however, there are definite indications of the origin of the disease. When Albizzias (*Albizzia moluccana*), planted through tea, are allowed to grow to a large size, and are then ringed or cut down and the stumps left to decay *in situ*, root disease frequently attacks the surrounding tea bushes. In some instances this is due to *Ustulina zonata*, but when a large number of bushes die, twenty or more, round an *Albizzia* stump, the cause is usually *Botryodiplodia*. The fungus develops on the dying *Albizzia* stump, and its spores subsequently infect the neighbouring tea. Similarly, the disease is prevalent, in some instances, where *Albizzia* prunings have been systematically buried; and it has occurred round *Hevea* stumps where *Hevea* in tea has been felled and the stumps left to decay *in situ*.

But the most probable reason for the occurrence of *Botryodiplodia* in old tea is to be found in the practice of burying prunings. The disease is undoubtedly worst on estates where prunings have been systematically buried over a long period. This may also explain why the disease is more prevalent in the low country where the tea is pruned every two years or less, than at higher elevations, where a longer time elapses between prunings. If *Botryodiplodia* is present, it will develop freely on the buried prunings, and

from them attack the roots of the tea. As is well known, tea roots tend to grow towards the masses of buried prunings, because the decaying matter retains moisture and is damper than the surrounding soil. In one instance, it was observed that the bushes first attacked were situated round the holes where prunings had been buried. The addition of the usual quantity of basic slag and sulphate of potash, 2 cwt. basic slag and 56 lbs. sulphate of potash per acre, to the prunings at the time of burial, does not make any difference to the prevalence of the disease.

Botryodiplodia Theobromae is a very common tropical fungus, though in the majority of cases in which it is known to cause damage it is either a wound parasite or a follower of some other disease. It is common on *Hevea* and cacao, especially on dead stems or fruits, and occurs on dadap, papaw, sugar cane, coconut, etc.

When this disease was first found on tea in Assam, it was suggested that it had been conveyed by the seed. The tea attacked was about four years old, and in each case it happened that the bushes had been raised from Dibrugarh village seed. "In fact, without reference to position, wherever the Dibrugarh village seed had been used there the plants had died, though not usually until after the first pruning, say at three years from seed. A similar case has recently been reported from Jorhat; the same class of seed was used four years ago, now the plants are dying out." On that supposition, the most important preventive measure was said to be care in the selection of seed from a guaranteed source. But subsequent experience has practically negatived that supposition. In the first place, the disease is too widespread to be attributable to the use of any particular seed. Secondly, it would scarcely seem probable that a disease conveyed in the seed would remain dormant for four years, until the plant was pruned, or, in its more usual occurrence on old tea, for some twenty years. The evidence would appear to indicate that the disease is due to the presence of the spores of the fungus in the soil, and that it is favoured by the burial of prunings on which the fungus can propagate itself.

Bushes killed by *Botryodiplodia* should be uprooted and burnt as soon as possible. It is best to burn them, or at

least char them, with the help of kerosene, because, if they are heaped and allowed to dry, they develop myriads of spores. Any prunings lying about the affected patches should be raked up and burnt at the same time. The affected soil should be forked over with lime.

When the bushes first begin to show signs of being attacked, by the yellowing of the leaves and the death of the young shoots, very many of them can be saved by promptly applying lime. About two pounds of air-slaked lime should be scattered round each affected bush, and lightly raked in. Where fields are known to be badly infected, and numbers of bushes die after each pruning, lime should be applied before the bushes are pruned. The quantity of lime will probably appear excessive to many planters who are accustomed to the idea that tea will not endure lime, but less than two pounds has proved of little use in checking the disease in the case of old tea, and four pounds per bush has been applied without injury to the plant.

Where this disease is known to exist, prunings must be burnt.

There is some evidence that where *Botryodiplodia* is common, branches may be killed back after pruning by the direct attack of the fungus on the branches, *i.e.* by infection by means of spores *via* the pruning cut. This could be prevented by spraying the bushes with Bordeaux mixture after pruning.

After an attack of *Botryodiplodia*, when the surviving bushes have come into leaf again, and the disease is, for the time being, arrested, all dead branches should be pruned off and burnt.

Red Root Disease

(*Poria hypolateritia* Berk.)

This has been a common root disease of tea in Ceylon since the first planting of tea on a large scale, subsequent to 1880. It was then found that certain jungle stumps, notably Bombu (*Symplocos spicata*) were, in the language of an older generation, " poisonous " to young tea, *i.e.* the tea in the immediate vicinity of such stumps died out. It is now known

that in such cases the cause of the death of the young plants is a fungus which travels from the jungle stumps and attacks their roots, and the particular fungus associated with Bombu stumps is *Poria hypolateritia*. When this was recognised to be a root disease, it was classed with others as *Rosellinia*, a name which for several years served for every root disease of tea in Ceylon.

Poria hypolateritia is, perhaps, the commonest cause of root disease in the higher tea districts of Ceylon. When it was first differentiated from other tea root diseases, the known cases of it were all in old tea, which had been established for very many years. But it is most probable that it had existed on such estates from the time they were first planted, for, with the extension of tea planting in Ceylon since about 1908, this disease has come into prominence as the root disease *par excellence* of young clearings. Its range has also proved to be greater than was previously supposed, and it is now known to occur extensively at medium elevations and, more rarely, in the low country.

The disease may be identified by the mycelial strands which the fungus forms on the exterior of the root (Plate II., Fig. 11). These are at first white and soft, but soon become compact, tough, and red or dark red. They form at first a network spreading over the root, but may subsequently expand laterally and fuse with one another here and there into continuous sheets. They differ from the strands of *Rosellinia* in being compact and smooth, those of *Rosellinia* being somewhat loose and woolly. The interior of these strands is white, and as they are usually damaged to some extent when the bush is dug up, the root has generally a mottled appearance, red and white.

In the majority of cases, especially on young tea, where the planter is watching the progress of the clearing and notes dead bushes immediately, the affected roots agree with the description just given. But if the bush has been dead for some time, or if the fungus has been growing on the root for a comparatively long time before the bush died, the appearance of the dead roots may be different. When they are old, the cords of mycelium change colour and become black, so that the general colour of the root, when it is dug up and the mycelium damaged, is black and white, instead

of red and white. A further difference arises in these older cases, in that the mycelium sometimes cements to itself sand, stones, or earth, as in the case of Brown Root disease. But even in the worst-encrusted cases, this disease can be distinguished from Brown Root disease by the general black and white appearance of the root, and the absence of any tawny brown patches. Moreover, it is usually possible in such cases to find some traces of red sheets or strands at the collar.

The effect on the wood of the root varies — from the specimens examined, one would say with the age of the bush. But this may be explained by the fact that young bushes, one or two years old, are killed more rapidly than older bushes, or that the sudden death of a patch of young plants may sooner attract attention. In young plants, the wood of the root is usually quite hard and shows no evident signs of decay. In old bushes, especially if they have been dead some time, the wood is soft, sometimes watery, and permeated by red lines and plates of a more or less gelatinous consistency. If these old decayed roots are placed in a covered glass dish, they develop an abundance of white fluffy mycelium in a very short time. There is often a very thin film of white mycelium between the wood and the bark.

The fructification is produced at the collar of the bush, either on the stem, or partly on the stem and partly on the surrounding soil. It takes the form of a thin flat plate, reddish or pinkish in colour, studded with minute holes, and lying flat on the stem (Plate II., Fig. 10). It may measure from one to four inches in diameter, and about one-sixth of an inch in thickness. It consists of a thin layer of tubes packed side by side, seated on a red horny basal layer. The margin is at first white and floccose, with a more or less radiating structure, but ultimately it becomes red and horny, like the basal layer. As it dries, the fructification separates from the stem and curls up at the edges, exposing the red, or red-brown, lower surface. It is often produced at the collar of young plants, before, or as soon as, they are dead.

As already stated, this disease is common in young clearings, whether on land formerly in virgin jungle or on old chena land. It usually occurs in patches, and generally

in the neighbourhood of a decaying jungle stump. Bombu stumps, *Symplocos spicata*, have the reputation of being the most frequent source of this disease, but it has also been found to spread from the stumps of *Doona zeylanica.* It has been found on Keppetiya (*Croton aromaticus* var. *lacciferus*), but in that instance it had probably spread to, and killed, this plant in the same way as the tea. It is most probable, however, that it can develop on the majority of jungle stumps, as it is a common jungle fungus in Ceylon, though usually found, in the jungle, on decaying logs. It has recently been found to spread to tea from the stumps of felled *Albizzia moluccana*, previously planted for shade and green manuring.

Fig. 57.—*Poria hypolateritia* : fructification on the stem of a tea bush. ×⅓.

Once established, by means of wind-blown spores, on a dead stump, the fungus spreads through the soil by means of free cords of mycelium (rhizomorphs), and attacks the surrounding tea. These rhizomorphs are at first white, but subsequently become thick, stout cords, with a tough red-brown outer coat. When old they become black. Good instances of this power of running free through the soil have been afforded by growing the fungus from diseased tea roots in pots of soil in the laboratory. In some cases the rhizomorphs spread through the hole at the bottom of the pot and produced the fructification on the outside.

Every effort should be made to get rid of this disease in young clearings. If it is not eradicated then, it will continue to spread and take an annual toll of the bushes indefinitely. In one case, where the disease had been known to exist from the first year after planting, 2200 dead bushes were removed in the sixth year from a field of twenty-six acres. It has proved very difficult to eradicate, once it has been neglected. Trenching is essential in the case of this disease,

as it spreads by mycelium underground. Any jungle stump in the affected patches must be dug out and burnt.

This disease is known to occur in Ceylon, Southern India, and Java.

Poria hypobrunnea Petch

The appearance of the roots of tea bushes attacked by this fungus is identical with that described for *Poria hypolateritia*, but the fructification is different. It is a flat plate, as in the latter, but is at first pale yellow, becoming reddish, and finally slaty grey (Plate III., Figs. 5 and 6). If cut when in the intermediate reddish stage, it will be found to be blackish brown internally, with a reddish tinge towards the surface; but when old, it loses all the red colour. The lower surface is blackish brown, fibrous, not horny: when it has grown on the surface of the stem it is generally compact, but if it has grown over soil it is often somewhat loose.

The fungus is a common jungle species in Ceylon. It has been known to cause root disease in *Hevea* since 1905, and it is commonly to be found on *Hevea* logs left to decay after thinning out. Several instances of its occurrence on tea have been recorded, and others may have been passed over as cases of *Poria hypolateritia*. It has been found to kill out *Tephrosia candida*, both among young rubber and among tea, after the *Tephrosia* had been lopped and mulched in for two or three years. In view of the fact that the fungus can attack tea, it would appear advisable to set a limit, say about two years, to the intercultivation of *Tephrosia candida* as a green manure among tea, and to uproot the *Tephrosia* after the expiration of that period. In the cases hitherto observed of this disease on tea interplanted with *Tephrosia*, the *Tephrosia* has been attacked first.

Poria hypobrunnea has been found to originate on jungle stumps, in the same way as *Poria hypolateritia*. In one instance, it was found spreading to the tea from jungle stumps twelve years old.

Trametes Theae Zimm.

This fungus was recorded as the cause of a root disease of tea in Java by Zimmermann. The disease occurred on an

estate in West Java, on bushes two and a half years old. The tap roots of the affected plants were covered with thick mycelium, which was at first red-brown, but finally became black. The wood exhibited a carmine-red coloration. Pieces of the diseased roots, when enclosed in a damp chamber, were covered with white mycelium in twenty-four hours. The fructification observed and described by Zimmermann was apparently quite young and very small. He states that it was thin, dirty yellow, flat, 5 to 8 millimetres in diameter, with pores 0·15 mm. diameter. The description of the diseased root would agree with either *Poria hypolateritia* or *Poria hypobrunnea*; that of the fructification would appear to accord best with the young stage of the latter species, but it is scarcely sufficient to enable any definite decision to be arrived at.

Zimmermann recorded that on one estate a group of one hundred bushes was killed by this disease.

Brown Root Disease

(*Fomes lamaoensis* Murr.)

This is the oldest root disease of tea known, it having been first recorded by Cunningham in India in 1887. It was subsequently described as a root disease of coffee in Java, and later as a root disease of *Hevea* in Ceylon and Malaya. The disease is evidently a common one throughout the Eastern Tropics, and, in addition to the plants already named, has been found to attack *Castilloa*, Ceara, cacao, Caravonica cotton, dadap (*Erythrina lithosperma*), coca, *Funtumia*, *Albizzia stipulata*, *Grevillea*, etc.

The earlier investigators of this disease were unable to discover the fructification. Later workers found occasional patches of what appeared to be a *Hymenochaete*, and the fungus was referred to *Hymenochaete noxia*, a species which was sent to Berkeley from Samoa as the cause of a root disease of the bread-fruit tree. Further investigations have, however, shown that the supposed *Hymenochaete* patches are merely abortive attempts to produce the fructification, the fungus being really a *Fomes*.

When attacked by this disease, the roots of the tea bush

are encrusted with a mass of earth and small stones to a thickness of three or four millimetres; and this crust may extend up the stem for a distance of two or three inches. It is cemented to the root by the mycelium of the fungus, which consists of tawny brown threads. Here and there these threads may be collected into woolly masses, either superficial, or in pockets among the earth and stones. In old cases, these masses of mycelium acquire a black, hard covering, sometimes with a brown, powdery outer layer. At the upper edge of the crust on the stem, there may be a dark brown, velvety patch.

FIG. 58.—Brown Root disease; mycelium and adhering soil, etc., on the tap root of a young tea bush. ×½.

Between the bark and the wood, there is usually a thin layer of white or brownish mycelium. The wood of the root frequently does not exhibit much evidence of decay, especially if the bush has been dug up as soon as it was dead, but in old cases it is permeated with yellowish-brown sheets, which assume a honeycomb structure and appear as a network of lines when the wood is cut (Plate III., Figs. 7 and 8). This last feature is much better developed in soft-wood trees, *e.g. Hevea*, than in tea.

The appearance of roots attacked by Brown Root disease is practically unmistakable. They might in some cases be confused with *Poria hypolateritia*, since in advanced cases of the latter the mycelium may similarly cement earth, etc., to the root. But the presence of brown mycelium among

PLATE III.

ROOT DISEASES

FIG.

1. *Fomes lignosus*, upper surface of fructification. $\times \frac{1}{2}$.
2. *Fomes lignosus*, lower surface.
3. *Fomes lignosus*, in section, showing the white context and coloured pores.
4. Mycelium of *Fomes lignosus* on a root.
5. *Poria hypobrunnea*, a fully developed fructification.
6. *Poria hypobrunnea*, a section of the fructification showing context and pores. $\times 3$.
7. Root attacked by Brown Root disease, showing brown lines internally.
8. Wood attacked by Brown Root disease, with brown bands in honeycomb arrangement.
9. *Fomes lamaoensis* (Brown Root disease), showing pores and zoned context.
10. *Fomes lamaoensis*, upper surface of bracket. $\times \frac{1}{2}$.

All natural size, unless otherwise stated.

ROOT DISEASES.

the earth and stones in the former disease is usually sufficiently clear to enable a correct identification to be made.

The fructification is rarely present on the cultivated plants killed by this disease. It has, however, been developed from the dead plants in the laboratory, and it has been found in the field on dead *Hevea*, tea, mango, etc. It is bracket-shaped, often irregular and consisting of several brackets fused together side by side, three or four inches broad, about half an inch thick, and very hard (Plate III., Fig. 10). On the lateral roots of mango and *Hevea* it may form a continuous border, running for several feet, on either side of the root, united by a resupinate part on the lower surface. The developing pileus is purple-brown, or almost black, with a yellow margin. When mature and dry, it is purple-brown to blackish brown, often with concentric, narrow, blackish zones, sometimes yellow-brown towards the margin, smooth, and sometimes concentrically furrowed. The lower surface is dark brown, or almost black, often with a greyish bloom. When broken in two, it is seen to consist of a thin, dark, hard outer crust, with brown, or yellow-brown, tissue internally, the latter usually zoned with curved lines parallel to the margin. The lower half of the section consists of a darker layer of vertical tubes in which the spores are produced (Plate III., Fig. 9).

In Ceylon, Brown Root disease in *Hevea* has been particularly associated with cacao stumps, where the cacao has been felled to make room for the rubber. The disease has been known to attack living Grevilleas, and to spread from the dead *Grevillea* roots to tea. It has also been found to spread similarly to tea from decaying stumps of Na (*Mesua ferrea*). In India, this disease (under the name of stump rot) was recorded by Watt and Mann as occurring round stumps of Sum (*Machilus odoratissima*), Bukhain (*Melia Azedarach*), Madar (*Erythrina*), Simul (*Bombax malabaricum*) Bela (*Semecarpus Anacardium*), Nahor (*Mesua ferrea*), and *Grevillea*, but it is probable that this list refers to a collection of various root diseases. Tunstall confirms the last three of these and adds *Erythrina indica*, Sonaru (*Cassia* sp.), and Neem (*Azadirachta indica*).

In many cases, however, this disease occurs in old tea where no stumps have existed for many years. In such

cases, the disease must originate on the tea bush, and the infection must be communicated by spores, probably conveyed by the wind. So long as only abortive fructifications, which did not produce spores, were to be found, this was inexplicable, but now that the fungus has been found to be a *Fomes*, it is clear that the fructifications on dead wood in the jungle will provide sufficient spores for the purpose. The spores fall from the brackets as a white powder, which often whitens the ground beneath them.

The progress of this disease is usually slow, and although the fungus produces external mycelium which fastens the earth to the roots, it does not appear to spread to any appreciable distance through the soil. Apparently the disease only passes from one bush to the next along roots which happen to be in contact. In Northern India it is said to be worst on sandy soils.

Dead bushes should be dug up and burnt, any neighbouring stump being removed at the same time. In general, it would appear that the whole of the fungus is removed with the dead bush, and it is rare to find the surrounding bushes attacked subsequently. The affected spot should be forked over with lime. Where a number of bushes have been attacked, or cases have occurred round a decaying stump, the affected area should be surrounded by a trench, but when only isolated bushes die trenching is seldom necessary.

Fomes lignosus Klotzsch

(*Fomes semitostus* Auctt., non Berk.)

Fomes lignosus, under the erroneous designation of *Fomes semitostus*, has been familiar to planters in the Eastern Tropics for many years as the cause of the principal root disease of *Hevea brasiliensis*, but in spite of the fact that *Hevea* was, in Ceylon at least, extensively interplanted through tea, it had not, until comparatively recently, been found to attack the latter. It is still of somewhat rare occurrence as a tea root disease, though it has caused serious damage to rubber by developing on tea stumps and spreading from them to the rubber in the interplanted fields, where the tea had been cut off at ground level after it had ceased to be remunerative.

In such interplanted fields, the tea must be uprooted when it has been decided to get rid of it. If it is merely cut down, each stump becomes a potential starting-point for *Fomes lignosus*, and, with stumps 4 feet apart, almost the whole field may become permeated by the mycelium of the fungus.

Instances of the occurrence of this disease on tea not contiguous to *Hevea* are as yet not numerous. In one case, in Ceylon, bushes were killed by it round an old jak stump; in another, round an unidentified jungle stump; and in a

Fig. 59.—*Fomes lignosus*, mycelium on root. $\times \frac{1}{2}$.

third, on tea near a cooly line where no stump existed, in this case probably introduced with firewood.

The diseased roots are covered with stout, rather flat, tough cords of mycelium which run more or less longitudinally and unite with one another to form a network. In colour they are white or yellowish; when fresh they may have a reddish tinge, which usually fades on drying (Plate III., Fig. 4).

The fructification is formed on the stem of the tea bush, from which it projects as a horizontal bracket. Frequently several occur one above the other. It is approximately semicircular in shape, two or three inches in diameter, and

one-quarter to half an inch in thickness, though it attains a much larger size on decaying stumps. When fresh, the upper surface is red-brown, with a yellow margin when immature, while the lower surface is bright orange (Plate III., Figs. 1 and 2). As the fungus dries, the red-brown colour of the upper surface gradually fades, not uniformly all over but in concentric zones, so that it becomes pale yellow-brown, with concentric darker lines.

The upper surface is not smooth, as a rule, but bears numerous grooves parallel to the outer edge; it is these grooves which retain the red-brown colour when the fungus is dry. Fine radiating striae run at right angles to the edge, and give the surface a silky appearance. The lower surface is studded with minute holes, which are the openings of the tubes in which the spores are produced; these holes are very small, and scarcely distinguishable without a lens.

The substance of the fructification is somewhat woody, but it breaks easily. The interior consists of two layers which differ from one another in colour and structure. The upper layer is white and fibrous, the fibres running more or less parallel to the surface, while the lower layer is red-brown and composed of closely packed tubes, perpendicular to the lower surface (Plate III., Fig. 3).

Tea bushes attacked by *Fomes lignosus* appear to be killed comparatively slowly. The effect of the disease is first manifested by the gradual fall of the older leaves, so that the bush becomes "thin," *i.e.* bears very little foliage. At this stage the roots may be covered with the strands of mycelium, but the death of the bush may not ensue until some months later. In one instance, the fructification had developed at the collar before the bush was completely dead, several of the branches on the other side still bearing green leaves.

In general, *Fomes lignosus* develops first on a jungle stump, or the stump of a shade tree, and its mycelium spreads underground from the stump to the tea. Jak stumps (*Artocarpus integrifolia*) and *Ficus* stumps are notorious offenders in this respect, and the stumps of large dadaps (*Erythrina lithosperma*) and Bois Immortelle (*Erythrina umbrosa*) frequently harbour this fungus. But the list of trees which may be attacked by *Fomes lignosus*, or the stumps of

which may serve as a starting-point for the fungus, is a long one, and new names are continually being added. It now includes Jak (*Artocarpus integrifolia*), *Ficus* spp., Bombax (*Bombax malabaricum*), Ceara (*Manihot Gláziovii*), cacao, *Afzelia palembanica*, Halmilla (*Berrya Ammonilla*), *Derris dalbergioides*, *Shorea* sp., *Livistonia cochinchinensis*, coconut, bamboo, etc.

Since the mycelium of *Fomes lignosus* spreads freely underground, affected patches must be isolated by a trench. Care must be taken to include within the enclosed area at least two rows of apparently healthy bushes, as, owing to the slow action of the mycelium on the root, it is probable that these will already have been attacked before the disease is discovered. Dead bushes, and any decaying stump, must be removed as completely as possible and burnt; even small pieces of roots will suffice to maintain the fungus and enable it to spread through the soil. Liming is not required, as it does not stop the growth of this fungus. The trench should be inspected periodically; if the fungus is still living in the soil, it will produce the fructification on the side of the trench and so furnish spores to carry the infection farther afield.

Lack of success in dealing with *Fomes lignosus* may usually be attributed to one of two causes: either the trench is not made far enough from the centre of the disease, or the diseased roots, including the lateral roots of the stump on which the fungus originated, have not been completely removed.

Fomes lucidus (Leys.) Fr.

This well-known fungus has been found to cause a root disease of tea in Northern India.

The cases which have been described were on old bushes which bore numbers of decaying snags, and it was thought possible that the spores of the fungus, which is a common species, might have infected the bushes through these. The mycelium of the fungus was very obvious both externally and internally. The wood attacked by it was darker in colour than the normal, and contained cavities filled with white mycelium, while the exterior of the root was covered with tough, thick white bands.

Fomes lucidus is known to be parasitic, in India, on many trees, including *Casuarina*, *Dalbergia Sissoo* (Shishan), *Acacia arabica*, *Cedrela Toona* (Tun, White Toon, or White Cedar), *Morus indica* (Mulberry), *Guazuma tomentosa*, and

FIG. 60.—*Fomes lucidus*; fructifications on the stem of *Limonia*. $\times \frac{1}{8}$.

the *Areca* palm. In Ceylon, it causes root disease of *Poinciana regia* (Flamboyante), mango, *Casuarina*, *Limonia alata* (Tumpat kurundu), *Albizzia moluccana*, *Oreodoxa*, the coconut palm, and bamboos. It is frequently common on decaying stumps of felled Albizzias, but has not been observed to attack the tea round such stumps.

The fructification of the fungus can hardly be mistaken for any other species. It is one of the bracket fungi, projecting horizontally from the stem of the host plant. Appearing first as a white swollen cushion, it extends horizontally into a plate which is roughly semicircular, one-half to four inches in thickness, and up to two feet or more in diameter. On a plant the size of a tea bush, however, its diameter would seldom exceed two or three inches. As it develops, its colour changes from white to yellow, and finally to some shade of red: it may be bright red, red-brown, chestnut, or a deep mahogany colour. Immature examples have a white margin, followed by a fairly broad yellow zone, and behind that the mature red coloration. But its chief characteristic, the one which distinguishes it from most other species, is its shining, varnished or lacquered, upper surface.

The lower surface of the fructification is white. Internally, the fungus is dark brown, and consists of two layers, an upper fibrous layer, and a lower layer of vertical tubes in which the spores are produced. When the spores are liberated, they are frequently deposited on the upper surface of the pileus as a brown powder. It is supposed that they are conveyed into that position by air currents.

When growing on coconut or bamboo, *Fomes lucidus* usually has a stalk, up to about four inches high and half an inch in diameter, deep chestnut or almost black in colour, and lacquered like the bracket. On dicotyledonous plants, such as tea, mango, etc., the stalk is, as a rule, almost suppressed, and is only represented by a narrow band round the broad base of the fungus.

Fomes applanatus Pers.

This fungus was found to cause a root disease of tea in Ceylon in 1918. It had previously been known to attack the roots of *Acacia decurrens* and kill the trees, and in South India it is known as the cause of a root disease of coffee. As usual, the disease has been found to be associated with decaying stumps in the few instances in which it has been observed. In one case only one bush was killed, and that was found to be resting on a decaying root of an Inga Saman (*Pithecolobium Saman*) which had been cut down, and the

stump left to decay. The fungus had spread from the decaying Inga Saman root to the tea bush at the point of contact. In another case the disease was associated with old, decaying *Grevillea* stumps.

There is no external mycelium evident on the diseased roots. The bark is blackened, and sometimes the roots bear small holes, up to three millimetres in diameter, which extend through the bark and appear white at the base. When

Fig. 61.—*Fomes applanatus*; fructification on a tea stem. $\times \frac{1}{6}$.

Fig. 62.—*Fomes applanatus*; fructification in the middle of a tea bush. $\times \frac{1}{8}$.

the bark is removed, small scattered patches of brownish-white mycelium are found between the bark and the wood; these usually adhere to the bark, and give it a mottled appearance on the inner side. When the root is split open, the wood has a mottled appearance, being minutely flecked with brown and white. These flecks are very small, and they are not arranged in a honeycomb fashion as in Brown Root disease. Any wood which has been exposed in the soil is blackened, with pockets of black or dark brown wood extending inwards.

The fructification of the fungus is produced on the main

stem, generally well above ground-level, about the point where it divides into the main branches. It is of the usual bracket shape, and from three to twelve inches in diameter. When extending outwards horizontally from the stem it is generally small, but it may form a mass up to a foot in diameter and several inches thick in the middle of the bush. Its upper surface is zoned, grey and brown, and has a very hard outer crust, but it is dull, not polished. The under surface is white. Internally it is dark brown, fibrous above, and with a thick layer of tubes below. When it produces spores, these are frequently deposited on the upper surface in a bright brown powder, as in the case of *Fomes lucidus*.

Fomes applanatus is one of the commonest bracket fungi on decaying stumps in the tropics, and is easily identified by its colour and its hard outer crust. But it is comparatively rarely found to attack living trees, and can therefore only be regarded as a weak parasite.

Treatment should follow the usual lines for root diseases in general. Dead bushes, and any neighbouring dead stump, should be dug up and burnt, and the patch forked over with lime. If a number of bushes are attacked in one spot, the patch should be surrounded by a trench. The lateral roots of the dead stump should be extracted as far as possible.

Polyporus mesotalpae Lloyd

This root disease has been found on tea in Ceylon on two occasions. The fungus has been known to attack the Moreton Bay chestnut (*Castanospermum australe* Cunn.) at Peradeniya, and it is not uncommon on decaying stumps of mango and cashew nut.

The photograph (Fig. 63) will give some idea of the size attained by the fructification of this fungus. In that case it grew up from the roots of the bush in a top-shaped mass about two feet in diameter which involved most of the branches. The branches were not killed by the fungus, but were merely embedded in the fructification. It is remarkable that, although the root may be in an advanced state of decay, the branches still appear healthy and bear leaves. Those on one side of the bush photographed were cut away to obtain a clear view of the fungus, which practically filled the whole

bush. The branches which are embedded in the fructification have their bark blackened externally.

The whole fructification is at first white and soft, but turns blackish brown when handled. It arises from a stout stalk which changes colour to a deep chocolate brown, and finally becomes black with a brittle outer layer. The upper part (pileus) becomes deep chocolate-coloured with a slightly velvety surface. There is a thin black layer just below the surface, which forms a brittle crust, while the remainder of

FIG. 63.—*Polyporus mesotalpae*; fructification on a tea bush. $\times \frac{1}{6}$.

the internal tissue is white, becoming reddish when cut. When old and dry, the surface is brittle and crusty, and the inner tissue is brownish grey, soft and spongy, or woolly, with its constituent hyphae radiating somewhat from the base. The pores in the top-shaped form are borne on the sloping sides.

When a bush is attacked by this disease, the tap root and the bases of the lateral roots become enclosed in a cement-like mass up to a foot in diameter. This consists of soil bound together by white floccose strands of mycelium. These strands run through the mass in veins and give it a

marbled appearance, while any cavity in the soil adjacent to a root is filled with a white floccose mycelium.

The bark of the diseased roots is blackened. In one case they did not bear any external mycelium, while in the other the roots were covered with white floccose mycelium, more or less in strands, but interwoven and forming a continuous coat. The wood of the roots is soft and friable, deeply coloured, black, or greenish black, or slaty black, sometimes brown in the centre.

In each of the recorded cases only a single bush was attacked. There is as yet no evidence that the fungus can spread through the soil to other bushes, though the occurrence of mycelium in the soil round the root strongly suggests that it can. It would be advisable, therefore, not to omit trenching when applying the usual treatment for root disease.

This disease has not been associated with decaying stumps in its occurrence either on tea or on *Castanospermum*.

Polyporus interruptus B. and Br.

This root disease has been recorded on three or four occasions in Ceylon, in most instances on old tea, where the main stems, in general, had undergone considerable decay from the top.

The bark of the diseased roots is blackened on the outside, usually in patches, and bears numerous minute white spots, congregated together on more or less definite areas. External mycelium is present in the form of stout white or yellowish cords, which are rounder and more elevated than those of *Fomes lignosus*; they are inclined to be hairy, or, in wet weather, loose and woolly. They usually extend above the collar along the main stem of the bush, and they may ascend along the larger branches after the manner of a Thread Blight. On cutting into the root, the bark is found to be blackened throughout, but there is no mycelium between the wood and the bark, and the wood, though slightly yellowish, does not show any marked signs of decay.

The fructification assumes various forms, according to its age and position. On the main stem of the bush, it is usually a white patch, with a fibrillose margin, which bears parallel vertical tubes lying side by side and united to one another.

On a vertical surface, the tubes are arranged in tiers. This is a *Poria* form, and is perhaps the commonest form met with on the tea bush. In addition to that, however, the fungus can produce small horizontal brackets, projecting from the stem, which bear the parallel tubes close-packed on the lower surface. This is the *Polyporus* form. The brackets,

FIG. 64.—Mycelium of *Polyporus interruptus* on the root of a tea bush. $\times \frac{1}{3}$.

as a rule, are not more than one centimetre in breadth, and are white and velvety on the upper surface when dry, but somewhat greyish when moist and sodden. They occur one above another in conspicuous masses.

The fungus spreads through the soil, and forms the fructification on dead leaves and twigs lying round the bush, or even on the soil itself. The dead leaves and twigs are often bound together into fairly large masses by the mycelium. On such twigs, and on surface roots, the *Polyporus* form is

generally produced, running along, and projecting from, one side of the twig. At first, separate brackets form, but these afterwards fuse into a continuous border. On the dead leaves, the *Poria* form is the more usual one—a thin circular sheet, studded with minute holes, the openings of the tubes referred to above, and bordered by a radiating, fibrillose margin. On the soil, patches of the *Poria* fructification are frequently produced in the hollows and cavities, while clusters of brackets occur on vertical surfaces. All these forms are common round infected bushes in wet weather. The formation of the fructification on debris round the tea bush is an indication that the mycelium of the fungus can spread freely through the soil.

FIG. 65.—*Polyporus interruptus*. 1, *Poria* form of fructification, natural size; 2 and 3, *Polyporus* form on a lateral root of tea, viewed from above, natural size.

In the instances observed, bushes have died in patches. The disease has not yet been associated with dead stumps. As the mycelium spreads through the soil, the affected patches must be isolated by a trench, and as much lime as is permissible must be forked in over the diseased area. All fragments of dead bushes, prunings, and dead leaves, should be raked together and burnt before the trench is dug and the lime applied.

Irpex subvinosus (B. and Br.) Petch

Irpex subvinosus was described by Berkeley and Broome from specimens collected in Ceylon by Thwaites about the

year 1870. The first intimation that it could be parasitic was obtained in 1916, when it was found to have attacked the roots of *Acacia decurrens* and tea. Apparently the *Acacia* had been attacked first, and the fungus had spread along the lateral roots. One of these roots had chanced to be in contact with a tea bush just below the collar, and the fungus had passed from the *Acacia* root to the tea bush at the point of contact, where the two roots were fastened together by a white pad of mycelium.

Since then, this fungus has been found, in several cases, to cause root disease in *Tephrosia candida* (Boga Medeloa), grown through tea as a source of green manure, more especially after the *Tephrosia* has been cut and mulched for about two years; and in one instance it attacked the tea as well as the *Tephrosia*, though only one or two tea bushes were affected.

The diseased roots are covered with a network of white strands. These are thinner than the strands of *Fomes lignosus* or *Polyporus interruptus*, and have a tendency to unite, or spread out, into thin, almost membranous, white sheets or patches. The wood of the root shows little evidence of decay at first, but ultimately becomes white and friable.

The fructification usually appears on the main stem or the branches of the bush, at some distance, six inches to a foot, above the level of the soil, and preferably on branches which run horizontally or obliquely. It arises from mycelium in the stem of the bush; the external strands on the root do not, as a rule, spread upwards over the exterior of the stem. It forms, on the under side of the branches, patches which vary from a deep purple when wet to a pale lavender colour when drier, usually with a white fibrillose margin. These patches bear numerous

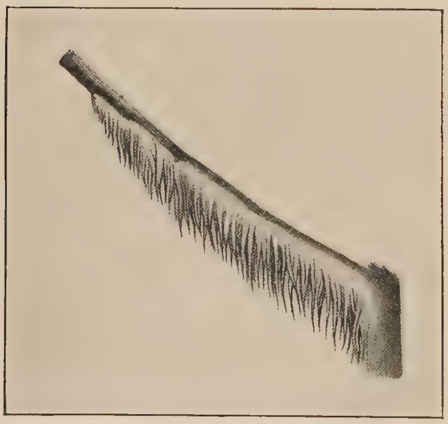

FIG. 66.—Fructification of *Irpex subvinosus*. Natural size.

vertical teeth, about five millimetres in length, moderately crowded together, either conical with pointed tips, or, more generally, triangular and flattened. When old and bleached, the fructification becomes yellowish or greyish white.

As already noted in connection with *Poria hypobrunnea*, *Tephrosia candida* should be uprooted and burnt, not left to decay, when it begins to die after repeated pruning.

Root-splitting Disease

(*Armillaria mellea* Vahl)

This disease has hitherto been recorded only from Java, where it is known to attack tea and cinchona. A similar disease on coffee in Java was described by Zimmermann in 1904.

The tap root and the lower part of the stem of the diseased bushes show longitudinal cracks in the bark and the wood, which are usually filled with compact fungus tissue. Between the bark and the wood, there is a thick white layer of mycelium which has a strong mushroom smell. Over the exterior of the roots run black strands, two to three millimetres broad.

The fructification has been developed by Rant in pure culture from the fungus on cinchona, and is considered by him to be identical with *Armillaria mellea*, a common " toadstool " round decaying stumps in Europe, where it is known as the honey mushroom from its colour, which is pale yellow to pale brown. The stalk and cap bear at first numerous, small, brown scales which weather off, leaving the fungus smooth. Round the stalk, towards the apex, there is, at first, a well-developed ring or curtain. Spores are produced in large numbers on the gills on the under surface of the cap.

As *Armillaria mellea* produces thick black cords of mycelium (rhizomorphs), which spread freely through the soil, it is essential that the diseased patches should be isolated by trenching. Search should be made for jungle stumps which bear the fructifications, and these stumps should also be removed, and their sites similarly isolated.

We give an illustration of a similar *Armillaria*, which

has been found to cause a root disease of *Acacia decurrens* in Ceylon. In this case, the bark of the root splits longitudinally, and the fungus forms a thick sheet of mycelium between the wood and the bark, but in the cases observed, this sheet, though white internally, has a red outer coat. The rhizomorphs of this species are also red at first, though they become black when old. This species is *Armillaria fuscipes*. It has a general resemblance to *Armillaria mellea*,

FIG. 67.—Fructifications of *Armillaria fuscipes* on a stump of *Acacia decurrens*. $\times \frac{1}{6}$.

but differs from it in its darker, blackish-brown stalk. The white covering over the soil in the illustration consists of the spores which have been shed from the under surface of the caps.

Root Diseases of Nursery Plants

The majority of the root and stem diseases which occur in tea nurseries are peculiar to seedlings. Few of these diseases have been completely investigated, but it appears from the available evidence that, in general, they are caused

by feebly parasitic soil fungi, and are not such as attack the full-grown bush.

In very many cases it is most probable that the soil conditions in the nursery favour the development of root and collar diseases. Too often, the nursery is established on a site which should never have been thought suitable. On a fully planted estate, it is no doubt difficult to find space for nurseries, but the sites of old cooly lines and cooly gardens are the last places which should be selected. Sour soil, and an abundance of soil fungi, are only to be expected in such localities.

The position of the nursery is often governed by the available water supply. In such cases, it must be remembered that it is very improbable that the same ground can safely be utilised for the purpose for several years in succession. After one batch of plants has been raised, the site of the nurseries should be changed, and the original ground should be left fallow for at least a year before being used again as a nursery. Nurseries should not be established on swampy soil, and if the site is at all inclined to be damp, it should be well drained.

As the plants have to remain in the nursery for a comparatively long time, it would seem preferable to plant the seed so far apart that the surface soil can be stirred at intervals without injury to the plants. The surface soil of tea nurseries is in many cases solidified, and it is impossible to alter that condition if they are closely planted. It is to be expected that wider planting and occasional surface cultivation would produce more vigorous plants.

"Bitten off" Root Disease

Bernard has described a disease of seedlings in which the primary root was attacked soon after it had emerged from the seed. The young white root, after attaining a length of about an inch, turned brown and rotted off from the tip upwards. In consequence, the young shoot (plumule) was unable to develop, and died before it had grown beyond the seed leaves (cotyledons). Bernard considered that the primary causes of this were a prolonged immersion of the seed in water during testing, and excessive dampness in

the seed bed at the time of germination. These factors induced conditions which weakened the young plants and favoured the development of the parasite. The fungus was not identified.

Fig. 68.—Root disease of germinating seeds. Natural size. (After Bernard.)

A similar disease frequently attacks older seedlings. The plants appear unthrifty, and are attacked severely by Grey Blight, Red Rust, etc. Ultimately they lose their leaves and die. On digging them up, it is found that the roots are decaying, and if the plants which are obviously affected but are not yet dead are examined, this decay is seen to begin at the ends of the finer rootlets. The description ordinarily given by correspondents is that the ends of the finer rootlets appear to have been bitten off, though no insect is found in the soil. The explanation of this appearance is that the decayed tips are left in the soil when the plant is uprooted. The disease progresses along the lateral roots towards the tap root, and in advanced cases the laterals are shrivelled and papery-looking. New roots may be produced at the collar, but these are in turn attacked. A *Rhizoctonia* has been found on the affected rootlets in some cases, and it is probable that this fungus is the cause of the disease.

Fig. 69.—"Bitten off" root disease. Natural size.

Sclerotium Disease

(*Sclerotium zeylanicum* (B. and Br.) Petch)

Tea seedlings are sometimes killed by a white fleecy mycelium which runs over the surface and in the upper layers of the soil. In general, it forms more or less continuous patches which gradually extend to a diameter of a foot or more, surrounding the stems of the seedlings and killing all it happens to meet. The affected roots, and the stems for a short distance, may be covered

with white strands, and the mycelium on the surface of the soil may assume the same form.

After the fungus has been growing for some time, small spherical or ovoid bodies appear on its surface. These are at first white, but subsequently become pale yellow or pale brown. They are about the size and shape of mustard seed in the majority of cases. These bodies are compact masses of mycelium, which are known as sclerotia. They separate from the mycelium and can undergo drying without injury. When the white mycelium dies, the sclerotia are left free in the soil, where they remain dormant until the next rainy period, when they give rise to the white mycelium again. No real fructification of this fungus has been observed; as far as is known, it is propagated only by these sclerotia.

The fungus is quite a common one, and may be found on dead wood and among dead leaves. It usually attacks plants with soft tissues such as Caladiums, but it has been known to kill plants with fairly well-developed wood, the Tree Daisy, for example. As a disease of tea nurseries, it is rare in Ceylon. It succumbs to the same treatment as the other root and collar diseases of tea nurseries, but it would be advisable to remove the mycelium and sclerotia by scraping off the surface layer of the soil on affected patches before watering with Jeyes' fluid, etc. The mycelium and sclerotia should be burnt.

Treatment of Nursery Root Diseases

In the root diseases of nursery plants referred to above, the fungi concerned appear to be weak parasites which readily yield to treatment with fungicides. Watering affected beds with lime-water is recommended in Java. In Ceylon, the remedy which has been used for several years, and, it would appear, with general success, is Jeyes' fluid, mixed with water at the rate of one ounce Jeyes' fluid to a gallon of water. After removing and burning the dead plants, the affected patches and the plants immediately surrounding them are well watered with the solution.

CHAPTER VI

WOUND COVERS, SPRAYS, AND SPRAYERS

Pruning Cuts

It has already been pointed out, in treating of Branch Canker, that decay often sets in from large pruning cuts, and, in consequence, open wounds are formed on the branches. Further, a description has been given of a stump-rot, caused by *Irpex destruens*, which attacks the main stem of a bush after it has been cut back. The latter decay may result in the death of the plant, while the former ultimately necessitates cutting well back along the larger branches, an operation which should be avoided as long as possible, as, if done repeatedly, it destroys the framework of the bush. It becomes a matter for serious consideration, therefore, whether pruning cuts should not be protected by some substance which will prevent, or at least retard, this decay. To a plant pathologist the proposition appears self-evident. The exposed wood must eventually decay, though probably owing to the close grain of the wood of the tea bush it does so very slowly. The fungi which bring about this decay are usually those which grow on dead wood in general, and the effect is no more to be attributed to the action of a specific disease than is the decay of a fence post.

At the present time, it may be said that the application of any protective to pruning cuts is the exception rather than the rule. On the younger tea, the rot is slow and apparently negligible, but an examination of old tea will generally show that the condition is progressive, and that many bushes bear long wounds extending from pruning cuts. This is usually dealt with by cutting back, but obviously that process cannot be repeated indefinitely. The periodical

treatment of the larger pruning cuts, half an inch or more in diameter, is calculated to postpone the time when drastic pruning of the main limbs of the bush becomes necessary.

Many experiments on the treatment of pruning cuts on fruit trees in temperate climates have been carried out, with the general result that cuts which were not treated have healed over more rapidly than those which were. But such experiments have very little application to tea. The pruning cuts under experiment were, as is usual on fruit trees, lateral, and consequently were such as would heal over, and become hidden by a new growth of bark and wood, naturally. But the pruning cuts on tea are terminal, and never heal over, at least under the conditions to which tea is subjected.

Experiments on the application of preservatives to pruning cuts on tea have been carried out in Java. The substances used included coal tar, Stockholm tar, and various brands of Carbolineum.

Coal tar gave very favourable results. It formed a protective coat over the wound, and did not penetrate to any considerable extent or cause any serious burning of the tissues of the stem. Buds developed even when their point of origin was covered by the tar. It penetrated farther when the tar was applied immediately after pruning than when the wound had dried, and consequently it is recommended that the application should be made twenty-four hours after pruning. It was not found to injure the coolies' hands.

The penetration of Stockholm tar was greater than that of coal tar, and it did not form a protective, weather-resisting coat. Hence it is not considered as good as coal tar for the present purpose. Moulds developed more freely on a cut surface treated with Stockholm tar than on one treated with coal tar. The growth of a callus was slower with Stockholm tar than with coal tar.

The various brands of Carbolineum tried were all considered unsuitable. They did not form a protective layer, and penetrated deeply into the tissues. They caused severe burning between the wood and the bark, which is the region from which the callus arises; consequently the growth of the callus was slow, and it began some distance below the cut.

The general conclusion arrived at was that ordinary coal tar, as it comes from the gas works, should be used, not mixed with any other substance. It should be used as thick as possible. If water has collected on the surface of the tar it should be removed before using the tar, as any injurious substances present in the tar become concentrated in it.

White lead paint has been recommended for covering pruning cuts in Northern India. In experiments on this point, carried out in temperate climates, white lead paint and white zinc paint, both mixed with linseed oil, have usually been found the most efficacious, and the former the better of the two.

Gondal Fluid

This mixture has been recommended in India for painting over pruning cuts, chiefly as a preventive of the attacks of white ants, though the claim has been made that it also prevents the attacks of fungi. As the ingredients can be obtained only in that country, the preparation has merely a local interest: and, moreover, it would not appear to afford such advantages as to render it worthy of universal adoption. For the protection of cuts against decay, other preservatives are more efficient. As, however, inquiries are frequently made for information concerning this fluid, the recipe is included for convenience of reference.

The substances required in the preparation of Gondal fluid are:

> One part dekamali resin (the resin of *Gardenia gummifera* or *G. lucida*).
> Two parts asafoetida.
> Two parts Bazaar aloes.
> Two parts castor cake.

These are well pounded, mixed, and kept in water for about a fortnight, using little more water than will cover them. At the end of that time they will have decomposed into a thick paste, and water is added to this to bring the mixture to the consistency of paint. It is customary to add a red colouring matter, such as red ochre, but the latter

is of value only as an indicator. The effect of Gondal fluid is said to last for two years or more.

Spraying Machines

The rapid spread of the practice of spraying during the present century, especially in the spraying of fruit trees, has led to the introduction of numerous labour-saving appliances. In many cases the spraying outfit consists of a force pump connected with a large reservoir of the spray fluid, the whole being mounted on some conveyance so that it may be taken along the rows of trees. In others, steam pumps have been employed to drive the fluid from a central station through numerous pipes to the operators, the pumping machinery and pipes being transferred from point to point as required. It will, however, be obvious that such devices cannot be employed on the average tea estate, and recourse must therefore be had to the earlier type of machine, viz. the knapsack sprayer.

Knapsack sprayers fall into two main classes, viz. those in which the liquid is expelled by continuous pumping, and those in which it is driven out by air pressure. In using the former, the cooly has to pump with one hand and direct the spray with the other, while with the latter he has merely to direct the spray. It appears to be the general experience in tropical countries, that the average cooly finds the first type of sprayer too fatiguing, and consequently does not do satisfactory work with it. For use on a large scale, the second type of sprayer appears to be the more preferable.

In one type of air-pressure sprayer, the liquid is poured into the tank, and the requisite pressure is then obtained by pumping in air, either by an independent pump, like a bicycle pump, or by a pump fixed to the sprayer. There is little to choose between these two, but in the case of the second, the pressure may be increased if necessary at any moment without returning to the base. In another type, the quantity of air in the sprayer is constant, and the pressure is obtained by forcing in the liquid and consequently compressing the contained air. Where sprayers of the second type have to be filled by a hand pump the operation of filling takes a long time, and this has led to their condemnation;

but special pumping apparatus has been introduced, by which this drawback has been removed. A collection of knapsack sprayers together with the central charging pump is known as a Battery. All pressure sprayers have the disadvantage that, after continued use, leakage occurs at the taps on the spray jet.

Knapsack sprayers are usually made to hold four gallons of the spray fluid, but smaller sizes to hold two gallons or one gallon are procurable. The weight of four gallons of liquid, a little over forty pounds, plus that of the sprayer, makes a rather heavy load for the average cooly, and an intermediate size, about three gallons, would perhaps be preferable. For spraying with Bordeaux mixture, or other copper solutions, the tank must be of copper, not iron, as the copper solution corrodes iron vessels and the spray liquid is converted into a worthless iron compound. But for sulphur solutions, iron tanks, not copper, must be used, because the sulphur attacks copper. The necessity of having two sets of sprayers has, however, been avoided by the invention of steel sprayers, lead coated, with a lining of Bitumen Mastic ; in these any of the ordinary spray fluids, copper, soda, or sulphur solutions, may be used.

Rubber and leather parts perish rapidly in the tropics, and consequently sprayers with metal valves are to be preferred. The working parts should be as simple as possible, and should be readily accessible for cleaning or examination.

The nozzle should deliver the spray in a fine mist. Those of the Vermorel type are usually the most satisfactory. It should be mounted on the delivery tube in such a way that the bushes may be sprayed from below ; this may be effected by a bend in the tube near the nozzle.

Sprayers should be washed out and cleaned after use, and should be periodically examined and tested. Where they are only used occasionally, it is rare to find one in working order when wanted.

Spray Fluids

The most effective fungicidal spray fluids are those which contain copper. The best of these are Bordeaux mixture, or the modification of the Italian form of that, known as Woburn

Bordeaux, both of which are copper-lime compounds, and Burgundy mixture, which is a copper-soda compound.

Bordeaux Mixture

Bordeaux mixture is made by mixing together a solution of copper sulphate and milk of lime. Different proportions have been recommended from time to time, but it is now usual to take equal quantities of lime and copper sulphate. 5 lb. of lime and 5 lb. of copper sulphate in 50 gallons of water may be used. This gives a nominal excess of lime, which is an advantage in countries where lime is generally very impure.

The milk of lime and the copper sulphate solution must be made separately and then mixed. It was formerly advised that each should be made up to 25 gallons before mixing, and the two then poured simultaneously into a third receptacle, but according to the Woburn authorities that is unnecessary, and better results are obtained by pouring a strong copper solution into the milk of lime.

The amount of copper sulphate which will dissolve in water depends upon the temperature. Roughly, at 50° F., 100 parts of water will dissolve 36 parts of copper sulphate, while at 70° F., 100 parts of water dissolve 40 parts of copper sulphate. As a gallon of water weighs 10 lb., 10 gallons of water will dissolve 36 lb. of copper sulphate at 50° F., and 40 lb. at 70° F. But in making strong solutions, allowance must be made for the lowest temperature to which the solution will be subjected, otherwise some of the copper sulphate will crystallise out as the solution cools. In practice, it is not advisable to try to work too near the actual limits. If stock solutions of copper sulphate are made, they should not contain more than two or two and a half pounds to the gallon.

In preparing Bordeaux mixture, dissolve the 5 lb. of copper sulphate in 5 gallons of water. The easiest way is to tie up the copper sulphate in a piece of sacking and suspend it at the top of a tub of water. The receptacle must not be made of iron or zinc. This solution should be begun the day before it is required.

Put 5 lb. of quicklime into a bucket, and slake it by

sprinkling it with a little water and leaving it for about half an hour or so to crumble down. Then mix it with more water so as to form a cream or milk, and finally pour it into a tub, adding water to make the quantity up to 45 gallons. This may also be done the day before using; the lime water deteriorates slightly owing to the absorption of carbon dioxide from the air, but if the liquid is undisturbed this action is confined to a surface film.

When required for use, stir up the 45 gallons of milk of lime and pour into it the 5 gallons of copper sulphate solution, stirring it just enough to secure complete mixing. This final mixture must not be made in iron or zinc vessels; a wooden receptacle is the best. Very little stirring is required after the final mixing.

If the sprayers are not provided with strainers, the mixture must be poured into them through a strainer which will remove any particles of sand, etc., which might block the tubes. It must be remembered that the fungicidal substance is the bluish-white powder which is suspended in the liquid, not the clear liquid which remains after the powder has settled.

It is customary to give tests to determine whether all the copper has combined with the lime, or whether any copper remains in solution. With the quantity of lime stated above, it is improbable that any dissolved copper will be left. If, however, it is desired to test the mixture the following method should be adopted. Put a few drops of a solution of potassium ferrocyanide into a white saucer with some water, and drop into this some of the clear liquid obtained after the Bordeaux mixture has been allowed to settle. If a brown or red coloration appears there is some copper left in solution. More milk of lime must then be added to the Bordeaux mixture, and the test repeated.

Woburn Bordeaux

Recent researches at the Woburn Experimental Fruit Farm have led to the recommendation of the following modified Bordeaux mixture, known as Woburn Bordeaux. With this mixture, much less copper is required, and clear lime water is used instead of milk of lime. The quantities

required are 1 lb. of copper sulphate to $13\frac{1}{2}$ gallons of clear lime water, with the addition of soft water sufficient to bring the whole to 76 gallons.

Dissolve 1 lb. of copper sulphate, as directed above, in 1 gallon of water. Slake about a pound of quicklime, and put it in a tub with about thirty gallons of water; stir up the mixture two or three times and leave it to settle until the liquid becomes quite clear. The clear liquid contains lime in solution, and is lime water. Run off $13\frac{1}{2}$ gallons of the *clear lime water*, and mix it with the copper sulphate, not in an iron vessel. Finally, add *soft* water to bring the whole mixture up to 76 gallons. As the lime in this preparation is reduced to the minimum, the liquid should be tested by the ferrocyanide method, and if the test shows that some copper still remains in solution more lime water must be added.

The advantages of the Woburn Bordeaux are (1) it requires a smaller quantity of copper sulphate and is therefore cheaper; (2) lime water is used instead of milk of lime, and with the poor quality of lime which alone is available in many districts, the former is more easily obtained in a satisfactory strength.

If soft water is not procurable, hard water may be softened by adding lime water to it. Water in a chalk district may be softened by adding about twenty-six fluid ounces of lime water to every 10 gallons, and even in the case of soft water or rain water four or five fluid ounces of lime water may with advantage be added to every 10 gallons to remove the carbon dioxide in it. This of course should be done before adding the soft water to the copper sulphate - lime water mixture.

The preparation of these spray fluids is no doubt a troublesome process, but it is within the capacity of the average dispenser. Attempts have been made to avoid all the trouble by manufacturing a paste which has merely to be mixed with water before using, and these have been successful, as far as temperate countries are concerned. But these pastes invariably decompose under tropical conditions, and up to the present no method of overcoming that appears to have been discovered.

Burgundy Mixture

This spray is more easily prepared than Bordeaux mixture, and has the advantage that there is no sediment to clog the sprayers. In districts where lime is not readily available, it offers a good substitute for the lime-copper sulphate sprays, and during recent years it has been steadily increasing in favour. It is claimed that it adheres longer to the plant, and is less easily washed off than Bordeaux mixture. It is somewhat more expensive than the latter, as the cost of soda is higher than that of lime. A mixture of copper sulphate and soda in the requisite proportions has been put on the market under the name of "Blighty" mixture.

Burgundy mixture requires:

5 lb. copper sulphate.
$6\frac{1}{4}$ lb. washing soda.
50 gallons water.

Dissolve the copper sulphate in about five gallons of water. Dissolve the washing soda in about the same quantity of water, and mix the two solutions, afterwards adding water to bring the total to 50 gallons. This constitutes what is known as a 1 per cent mixture.

An Adhesive Mixture

To increase the adhesive properties of Bordeaux or Burgundy mixture, the following solution may be added. Dissolve 1 lb. of washing soda in 1 gallon of water, and boil; then add 2 lb. of resin, and boil for about an hour, keeping the mixture well stirred. One gallon of this solution should be added to 24 gallons of Bordeaux or Burgundy mixture.

Lime-Sulphur Solution

This may be used, after pruning, to remove Thread Blight or Horse-hair Blight from the main branches and stems of the bushes. In such cases it may be applied with a brush of coir or other material. The following is one method of preparation.

Slake 4 lb. of quicklime, and put it in an iron drum or boiler with about six gallons of water. The drum should

be capable of holding about twelve gallons of fluid, and should be marked inside at the 10-gallon level. Boil the lime and water mixture, and when boiling add $4\frac{1}{2}$ lb. of sulphur gradually, stirring the mixture all the time. When all the sulphur has been added, pour in boiling water to bring the level up to the 10-gallon mark, and boil for an hour longer, keeping the total volume at 10 gallons by adding *boiling* water. When cool, this forms the stock solution; for use, it should be diluted with ten times its volume of water.

Flowers of sulphur must be used in preparing this solution. If it is desired to keep the stock solution for some time, it should be stored in full, air-tight vessels. Lime-sulphur solution must not be stored in copper vessels, nor used for spraying from copper sprayers. After being used with this solution, all sprayers should be thoroughly washed out and cleaned.

Alkaline Washes

The following washes or sprays have been recommended for application to the stems of tea bushes to remove mosses and lichens, and to bushes which are hidebound.

(1) 2 lb. caustic soda, 98 per cent pure, dissolved in 10 gallons of water. This gives a clear solution which can be applied as soon as the soda has dissolved. If a less pure soda is used, the amount must be increased proportionately.

(2) 7 lb. washing soda crystals and 2 lb. quicklime in 10 gallons of water. The soda should be dissolved in the water, the quicklime added, and the mixture well stirred, the stirring being repeated at intervals for a day before using. The interaction of the washing soda and the quicklime produces caustic soda and carbonate of lime, so that the liquid is equivalent to that of the preceding formula. It has, however, the advantage that the treated bushes are whitewashed, and consequently the work can be easily checked. In the preparation of the mixture, the vessel in which it is made should be kept covered during the intervals between stirring.

(3) $2\frac{1}{2}$ lb. of dry carbonate of soda (in powder) and 2 lb. of quicklime in 10 gallons of water. Mix as in (2). The remarks under (2) apply to this mixture also.

These soda washes must not be applied to leaves or young wood. They can therefore only be used after the bushes have been clean pruned. In temperate climates, where these or similar mixtures are used as winter washes, it has been found that, though a single application does no appreciable harm to stems, they cannot be applied annually without injury to the bark. This consideration, however, is not likely to arise in the case of tea in Ceylon, if the application is restricted to the pruning period ; but it must be taken into account in districts where the bushes are pruned every year. The application should be restricted to one year in four.

Copper Soda Emulsion

(Woburn Winter Wash)

This has been recommended in Northern India for the treatment of Velvet Blight ; and as it is a combined insecticide and fungicide its use is indicated in similar diseases in which the occurrence of the fungus depends in the first instance on the presence of scale insects.

The ingredients of this wash are :

Copper sulphate	1½ lb.
Quicklime	½ lb.
Kerosene	5 pints.
Caustic soda	2 pounds.
Water	9½ gallons.

The copper sulphate is dissolved in about eight gallons of water in a wooden vessel. Half a pound of fresh lime is then slaked, and made into a milk with water, and added to the copper sulphate solution, being run through a piece of sacking to remove sand and coarse particles. The mixture is then churned up with 5 pints of kerosene, 2 lb. of soda are added, and the whole made up to ten gallons.

Kerosene with a high boiling-point, such as Solar Distillate, gives better results than the ordinary kerosene used for lighting.

CHAPTER VII

MYCOLOGICAL NOTES

Pestalozzia Theae Sawada.—Massee decided that the tea *Pestalozzia* was *Pestalozzia Guepini* Desm., a species which occurs on *Camellia japonica* in greenhouses in Europe, and a great part of his account of Grey Blight deals with the fungus on that plant, not with the fungus on tea. In 1907, Bernard, who had studied the species of *Pestalozzia* on tea and coconut in Java, decided that the former was not *P. Guepini*, but was identical with that on coconut, viz. *Pestalozzia palmarum* Cooke. In the Quarterly Journal of the Indian Tea Association, 1916, however, it was recorded that Butler had examined Cooke's type specimen of *Pestalozzia palmarum*, and had found that the spores of that species were smaller than those of the species on tea. Meanwhile, Sawada had named the *Pestalozzia* which occurs on tea in Formosa, *Pestalozzia Theae*, and the latter is undoubtedly the same as that on tea in India and Ceylon. The spores in the type of *Pestalozzia palmarum* measure $15\text{-}21 \times 5\text{-}6\ \mu$, and are smaller than those of the *Pestalozzia* found on tea, which are $20\text{-}35 \times 5\text{-}11\ \mu$. Sawada's name is consequently adopted.

Colletotrichum Camelliae Massee.—The other species of *Colletotrichum* and *Gloeosporium* which have been recorded on tea are *Colletotrichum Carveri* Ell. and Ev., from North America, conidia $12\text{-}15 \times 3{\cdot}5\text{-}5\ \mu$, setae $40\text{-}80 \times 3\ \mu$; *Gloeosporium Theae* Zimm., from East Africa, conidia $14\text{-}19 \times 4\text{-}6\ \mu$; and *Gloeosporium Theae-sinensis* Miyake from Japan, conidia $4\text{-}6 \times 2\ \mu$. In *Colletotrichum Camelliae*, the conidia are $10\text{-}18 \times 4\text{-}5\ \mu$, and the setae in the normal acervuli vary from $36 \times 4\ \mu$ to $135 \times 7\text{-}8\ \mu$. It is most probable that *Colletotrichum Carveri* and *Gloeosporium Theae* are identical with *Colletotrichum Camelliae*. *Gloeosporium* forms of the latter, with minute acervuli, $120\ \mu$ diameter, and conidia, $14\text{-}18 \times 4\text{-}5\ \mu$, have been found on tea twigs in Ceylon. *Gloeosporium Theae-sinensis* would appear distinct in its smaller conidia. But the minute acervuli which occur with *Guignardia Camelliae* frequently have small spores, and specimens of *Colletotrichum Camelliae* on tea twigs have been examined in which the spores were oval, $3\text{-}6 \times 2\text{-}3\ \mu$, and the setae, $16\text{-}32\ \mu$ long; the setae in this case

formed a complete ring round the acervulus and were hidden beneath the ruptured epidermis.

Guignardia Camelliae (Cooke) Butler.—This was originally described from Johore by Cooke as *Sphaerella Camilleae*, the name being changed to *Laestadia Camilleae* by Berlese and Voglino. On the same leaves there occurred a pycnidial fungus, which Cooke named *Phoma Camilleae*. Subsequently Raciborski collected a fungus on tea in Java which he named *Laestadia Theae*, this name being changed later to *Guignardia Theae* by Bernard. Zimmermann, in 1902, suggested that *Guignardia Theae* was identical with *Sphaerella Camelliae*. The type specimen of the latter in Herb. Kew has been examined by Butler, who has affixed to it a note stating that it is identical with *Laestadia Theae* and with the fungus which causes Copper Blight in Northern India. The author has also examined the same specimen, and is of opinion that it is identical with the species which has been recorded from Ceylon as *Laestadia Theae* Rac. There is therefore general agreement that *Guignardia Camelliae* occurs in India, Ceylon, and Java.

Raciborski stated that he found *Colletotrichum Camelliae* Massee on the same spots as *Guignardia Theae*, the spores of the former measuring 7-9 × 3-4 μ, and he suggested that the *Colletotrichum* was the conidial form of the *Guignardia*. The same condition is found in Ceylon. Shear and Wood, from an examination of diseased leaves of tea found on greenhouse plants in America, stated that *Colletotrichum Camelliae* was undoubtedly the conidial form of *Glomerella cingulata* (Stonem.) S. and v. S., and included *Laestadia Camelliae* (Cooke) Berl. and Vogl. as a synonym of the latter. Indian mycologists, however, though agreeing with Shear and Wood that the perithecia which accompany *Colletotrichum Camelliae* are *Glomerella cingulata*, maintain that *Guignardia Camelliae* (Cooke) is a different species.

Shear and Wood give the dimensions of the ascospores of *Glomerella cingulata* as 9-24 × 3-7·5 μ, the range on tea being 10·5-24 × 4-7·5 μ. Raciborski described the perithecia of *Guignardia Theae* as 90-115 μ diameter and the ascospores as 10-12 × 4-5 μ, while Bernard, who compared his specimens with Raciborski's type, gave the ascospores as 12-16 × 5-6 μ. Bernard did not find *Colletotrichum Camelliae* on the leaves bearing *Guignardia Theae* which he collected. Butler gives the perithecia of *Guignardia Camelliae* as up to 250 μ diameter, with ascospores 12 × 5 μ, and the perithecia of *Glomerella cingulata* on *Ficus* as about 100 μ diameter, with ascospores 14-19 × 3·5-5 μ. Tunstall and Bose give the perithecia of *Glomerella cingulata* on tea as up to 160 μ diameter, with ascospores 12·5-18 × 3·5-5 μ, and the perithecia of *Guignardia Camelliae* as about 100 μ diameter, with ascospores, 13·5-15·5 × 6-7·6 μ. In Ceylon, the perithecia which accompany normal *Colletotrichum Camelliae* on tea are up to 250 μ diameter, not beaked, with spores 8-17 × 4-5 μ in the same perithecium, and a range of 8-18 × 3·5-5 μ.

There does not appear to be any constant character by which these perithecial forms can be separated. It is to be observed that *Glomerella* is a "culture" genus, and it is very doubtful whether it can be distinguished from *Guignardia* in nature. The weft of hyphae required by the generic description certainly does not occur with the perithecia which accompany *Colletotrichum Camelliae.*

Further complicating this question are the minute crater-like spots which accompany *Guignardia Camelliae.* The fructification which precedes these spots was named *Phoma Camilleae* by Cooke, who gave the spore measurement $10 \times 5\ \mu$. Shaw who examined them in India described the spores as furnished with a mucilaginous appendage. Raciborski stated that these fructifications were *Colletotrichum Camelliae*, and gave the spore measurement $7\text{-}9 \times 3\text{-}4\ \mu$. Tunstall and Bose describe them as black pycnidia with short beaks, but they state that the upper part of the pycnidium wall disintegrates when mature, from which it would appear that the pycnidia are not ostiolate ; these authors also state that the spores, which measure $10{\cdot}85\text{-}12 \times 6{\cdot}5\text{-}7{\cdot}5\ \mu$, are detached from the pycnidial wall retaining their pedicels or basidia.

In Ceylon, this pycnidial fructification may be found with the perithecia of *Guignardia Theae*, or with typical acervuli of *Colletotrichum Camelliae*, or occurring alone. In the latter case, the spots bear numerous minute black points which, viewed macroscopically, appear to be true pycnidia. When sectioned and mounted, however, it is found that these are not true pycnidia ; the upper part of the sphere is thin, fuscous, apparently composed of one layer of cells, and there is no ostiolum. When mature, the upper part breaks irregularly, as in *Colletotrichum.* The spores are broadly oval, $5\text{-}8 \times 3{\cdot}5\text{-}4{\cdot}5\ \mu$. These fructifications are frequently situated beneath the stomata. After the spores have been liberated, they appear as minute brown craters, the colour being due to the exposed tissue of the leaf.

On the leaves which bear *Colletotrichum* or *Guignardia*, the old crater-like spots do not show any pycnidium. Prior to the formation of the crater, there is a pseudo-pycnidium, identical with that described above. The spores in these examples vary : some are broadly oval, $8\text{-}14 \times 3\text{-}5\ \mu$, others narrow-oval, $9\text{-}16 \times 2\ \mu$. In many cases, short aborted setae, up to $16\ \mu$ long, occur at the edge of these craters, usually hidden beneath the ruptured epidermis. No mucilaginous appendage has been observed, but the spores sometimes show a slight contraction into a peg-like base.

From these facts it would appear that *Phoma Camilleae* Cooke is really a state of *Colletotrichum Camelliae* Massee.

It may be pointed out that Cooke named his second species *Phoma Camilleae* in 1884, and in 1887 Passerini named another species *Phoma Camelliae.* Hence Cooke's name cannot now be corrected to *Phoma Camelliae.*

Phoma theicola Petch differs in having a black parenchymatous pycnidial wall, and in being definitely ostiolate.

Hendersonia theicola Cooke.—Massee claimed that Cooke's fungus was not a *Hendersonia*, but a form of *Pestalozzia Theae*, in which the characteristic setae were not developed, as he obtained such forms in his cultures of *Pestalozzia*. That view was strongly opposed by Speschnew, who stated that in culture the *Hendersonia* spores never produced setae, while a *Pestalozzia* culture which had produced spores destitute of setae yielded normal setiferous spores later. Aborted or imperfect *Pestalozzia* spores are common, but more so in nature than in culture; in the latter, they tend rather to a greater luxuriance of setae than to the suppression of setae or septa. It is to be noted that the *Pestalozzia* cultivated by Massee was that on *Camellia japonica*, not the one on tea; and further, with regard to Cooke's specimen, that it is usually possible to find *Pestalozzia* spores on any diseased tea leaf.

The fungus which is regarded as *Hendersonia theicola* in Ceylon has minute pycnidia, about 50 μ diameter, furnished with a distinct ostiolum. Its spores are narrow-oval or subcylindrical, three-septate, slightly constricted at the septa, rounded at the ends, fuliginous to pale brown, $8\text{-}10 \times 3{\cdot}5\text{-}4\ \mu$. It has been found on "scabbed" leaves, and with Grey Blight. In one case, the *Pestalozzia* spores on the same leaf, in close proximity to the *Hendersonia*, measured $28\text{-}34 \times 8\text{-}12\ \mu$. These *Hendersonia* spores could not by any effort of imagination be considered abnormal *Pestalozzia* spores.

Cephaleuros.—Cunningham named the species of *Cephaleuros* on tea and other plants examined by him, *Mycoidea parasitica*. There is not much doubt that he included more than one species under that name. Subsequently Hariot referred the superficial species described by Cunningham to *Cephaleuros virescens* Kunze, a species collected in Cuba, and described in 1829. There is no type specimen of the latter, and the description is inadequate; consequently Karsten (1891) in his paper on the *Chroolepidae* of Java rejected Kunze's name and adopted the name *Cephaleuros mycoidea*. As Karsten's determinations are the first which can be definitely interpreted, they are followed here.

Bacillus Theae Hori and Bokura.—Rod-shaped, rather large, varying in size with the medium and the age of the culture, usually $1{\cdot}4\text{-}1{\cdot}8\ \mu$ long, $0{\cdot}8\text{-}1\ \mu$ broad, ends rounded, frequently in chains of two or three; rapidly producing spores within three or four days; furnished with 6 to 8 flagella from round the body, actively motile. Decolorised by Gram's method. On normal agar, forms pale greyish-white colonies, the medium becoming dark brown with age. On potato, the colonies are pale greyish white, changing later to a straw colour. With the addition of glucose, saccharose, or glycerine, the growth increases proportionately up to a certain limit. Liquefies gelatine, but does not coagulate milk nor ferment sugars (glucose, saccharose). Bouillon shows a weak indol reaction after one week. Anaerobic growth poor.

Thread Blight.—Specimens of Thread Blight on tea were sent from India to Berkeley about 1873. Berkeley named the fungus *Corticium repens*, but stated that he had been unable to detach the spores so

as to ascertain their form and nature. No type specimen of *Corticium repens* is now available. From a figure published by Berkeley in the *Quarterly Journal of Microscopical Science*, xv., n.s. (1875), p. 131, it would appear that he had one of the Thread Blights, not the Black Rot fungus, but in the absence of a specimen it is impossible to say which.

In 1898, Massee described an Indian Thread Blight on tea as *Stilbum nanum*. The type specimen of *Stilbum nanum* in Herb. Kew, however, though it is the specimen figured by Massee, does not bear any Thread Blight. Hence it is not possible to state definitely to which species of Thread Blight Massee intended to apply that name. A few years later, Massee received further specimens of Thread Blight on tea from India, and these he named, and included in Herb. Kew as *Stilbum nanum*. But these latter specimens bear fructifications which show that they are identical with the epiphytic species of Ceylon, *Marasmius pulcher*. The imperfectly developed form of this species was named *Cyphella pulchra* by Berkeley and Broome in 1873.

The bulk of the hyphae of the cords of these Thread Blights are about 3 μ in diameter, thick-walled or solid, and are thereby readily distinguished from the Black Rot fungi. Thin-walled septate hyphae occur chiefly at the base of the thread. The anker cells of the parasitic species, in the available Ceylon and Indian examples, are, for the most part, spherical or oval with apical and basal points, 12-24 $\times$ 8-10 μ: examples which bear a ring of projections round the middle, as figured by Zimmermann, are rare. The ultimate branches of the hyphae of *Marasmius pulcher* are extremely fine, and are branched in a dendroid fashion.

Nectria cancri Rutgers.—This species is identical with *Nectria haematococca* B. and Br. The latter is very common in Ceylon, where it occurs on *Hevea* and cacao bark and pods which have been attacked by canker (*Phytophthora Faberi*), as well as on other dead plant tissues. It would seem probable therefore that the Indian species on tea has been misidentified.

Macrophoma theicola Petch.—This is the cause of the common branch canker of Ceylon, formerly attributed to *Nectria*. The first stage observed is a *Cytospora*, but this is only evident in very wet weather. The perithecial stage was originally described as *Physalospora neglecta*, but it falls into the recently instituted genus *Desmotascus*.

Corticium salmonicolor B. and Br.—As the cause of a disease, this fungus was described (1901) by Zimmermann in Java under the name of *Corticium javanicum*. Previous to that, a different fungus had been described (1899) as *Aleurodiscus javanicus* P. Henn., and when the latter was included by Saccardo in Sylloge Fungorum, its name was changed (1902) to *Corticium javanicum* (P. Henn.) Sacc. and Syd., as Saccardo did not then recognise the genus *Aleurodiscus*. Consequently, when Zimmermann's fungus came to be included in

the Sylloge, the name *Corticium javanicum* had been used, and Zimmermann's species was therefore renamed *Corticium Zimmermanni* Sacc. and Syd. (1902). In 1906, Pink Disease was found in Ceylon, and as the fungus was undoubtedly the same as the Javan species, Zimmermann's name, *Corticium javanicum*, was adopted for it, Saccardo's alteration being obviously invalid. There has never been any doubt that the Pink Disease of the Eastern Tropics is caused by the same fungus in all countries, the only point considered doubtful in some quarters being the particular name to be adopted for it. In 1911, however, the writer found that the fungus had been named *Corticium salmonicolor* by Berkeley and Broome in 1873, on specimens sent from Ceylon by Thwaites; and, unless some earlier name is discovered, that is the correct name of the Pink Disease fungus. At the same time, the writer suggested that the fungus of the similar Pink Disease of the West Indies, which was said to be *Corticium lilacino-fuscum* B. and C., had been wrongly identified. That suggestion has been followed up, and it is now known that the West Indian Pink Disease is also caused by *Corticium salmonicolor* B. and Br.

Corticium salmonicolor sometimes forms a fructification embedded within the bark. The outer layers of the bark subsequently rupture and disclose an orange-red mass of spores, in a circular or irregular cup formed by the ruptured bark. This form was named *Necator decretus* by Massee. It was found on tea in Java by Zimmermann, and has occurred on coffee, *Hevea*, *Amherstia*, etc., in other countries. The spores are irregularly oval or spherical, hyaline, $6{\cdot}5\text{-}21{\cdot}5 \times 8{\cdot}75\text{-}35\ \mu$.

Nectria cinnabarina (Tode) Fr.—Tunstall gives the following description of this species on tea. Perithecia 0·2-0·4 mm. diameter, solitary or clustered, sometimes arising from conidiophores, usually on a pulvinate stroma, dark red, becoming brown and sometimes black, spherical with a conical ostiolum, covered with hairs which are sometimes granulated; asci $47\text{-}65 \times 11\ \mu$, cylindric or clavate, slightly attenuated above, eight-spored, spores biseriate; spores oblong, slightly curved, one-septate, hyaline, longitudinally striate, $10\text{-}15 \times 5\ \mu$. *Tubercularia* stage, pulvinate, pink, 0·8 mm. diameter; conidiophores branched; conidia oval, hyaline, $7{\cdot}5\text{-}10 \times 3\text{-}3{\cdot}75\ \mu$. *Fusarium* spores, 4-11-septate, $37\text{-}60 \times 3\text{-}3{\cdot}5\ \mu$. The villous perithecia do not agree with *Nectria cinnabarina*, and the conidial stage is different.

Stilbella Theae Bern.—This species would appear to be very close to, if not identical with, *Stilbum nanum* Massee. Massee described his species as yellow, but from the type specimen it was evidently red when fresh. *Stilbum nanum* has never been observed to be other than saprophytic in Ceylon.

Irpex destruens Petch.—This is identical with the fungus recorded from Ceylon by Berkeley and Broome as *Irpex zonatus* Berk. Lloyd states that the latter identification was incorrect.

Septobasidium (Velvet Blight).—Blue when fresh, purple-black when dry, up to 0·8 mm. thick, structure stratose, not columnar

internally. Basal layer variable, when overrunning scale insects, densely interwoven and solid, with small cavities, some of which contain hyphae bearing globose spores, 4-6 μ diameter, elsewhere a thin layer of interwoven hyphae: above the basal layer, alternate loose and dense layers of interwoven hyphae. Hyphae purple-brown to hyaline, 3-4 μ diameter.

Septobasidium sp. –The species figured on Plate II. clothes the stems of seed bearers for a length of several feet. Towards the advancing margin it is slate-coloured, transversely zoned, with a white fibrillose edge. The older parts are purple-grey or brownish grey, even or slightly nodular, compact, cracking into more or less rectangular areolae, up to 0·8 mm. thick, stratose, composed of loosely interwoven, dark brown, regular hyphae, 3 μ diameter, which ultimately fuse and form an irregular, continuous network in section. The protobasidia are spherical or pyriform, 10-14 μ diameter.

Grey Fungus of the Dadap.—The following is the description of the grey *Septobasidium* which occurs on dadaps in Ceylon. Patches irregularly circular or oval, up to 8 cm. diameter, even, rather dark purple-grey with a reddish tinge here and there; lacunose at the margin, with slight radial ridges there on the basal layer, but no evident pillars. Thickness in the older parts, 0·4 mm.; basal layer 0·15-0·2 mm. thick, compact, almost parenchymatous, containing laterally-oval cavities up to 0·5 mm. long, 0·2 mm. high, red-brown, with a dark, dense line separating it from the middle layer: middle layer loose, 0·05-0·1 mm. thick, red-brown, composed of thick-walled, red-brown hyphae, 3 μ diameter; upper layer compact, 0·15 mm. thick, composed of more or less parallel erect hyphae. Protobasidia elongated-oval, hyaline becoming brownish, thin-walled, $16\text{-}26 \times 8\text{-}10\ \mu$.

Rhizoctonia sp.—The fungus referred to under this name, as ringing the new shoots of collar-pruned bushes, has a yellow-brown mycelium, consisting, in the older parts, of hyphae up to 16 μ diameter, with walls 2 μ thick, branching at a wide angle with expansions at the forks, irregular, with frequent angular projections of the walls, and without septa. From these arise similar hyphae, 10 μ diameter, cut off by a septum from the parent hypha, which diminish to, or give off branches of, a diameter of 3-5 μ. These finer hyphae are thin-walled and hyaline. Occasionally a hypha, 12 μ diameter, may be regular, thin-walled, and closely septate for a considerable distance. Terminal oval swellings, up to $40 \times 28\ \mu$, cut off by a septum from the parent hypha have been observed on hyphae 4 μ diameter.

It would seem possible that the above fungus may be identical with *Protomyces Theae* Zimm., described by Zimmermann in 1901 as occurring partly on the surface of, and partly within, the roots of tea in Java. The mycelium was yellow-brown and thick-walled. Within the root the hyphae bore terminal or lateral, irregularly globose, thick-walled swellings, up to $140 \times 220\ \mu$, usually several

together. Zimmermann considered that these swellings might be asci, but he did not observe any formation of spores. It was not determined whether the fungus was parasitic or saprophytic.

Rosellinia arcuata Petch.—This is the species recorded by Carruthers as the cause of root disease in tea in Ceylon, under the name *Rosellinia radiciperda* Mass. Subsequently it was referred by the writer to *Rosellinia bothrina* B. and Br., from Berkeley and Broome's description. An examination of the type specimen of the latter, however, showed that it did not correspond to the description, its spores being obtuse, not "very acute." The spores of the type of *Rosellinia bothrina* are narrow-oval, subcymbiform in one aspect, ends rounded, 28-38 × 8-11 μ, while those of the species parasitic on tea are cymbiform, 40-47 × 5-7 μ, with ends acute and often suddenly contracted in the last 3 μ. It will be evident that the shape of the spore is quite different in the two species and cannot be regarded as a "minute difference." This second species was sent to Berkeley and Broome at the same time as *Rosellinia bothrina*, but was referred by them to *Rosellinia aquila* Fr., which it is not. Consequently it was necessary to find a name for it, and the specific name *arcuata* was adopted, from the shape of the spores (cf. *Ann. Perad.* vi. p. 175).

The possible explanation of the discrepancy between Berkeley and Broome's description and the type specimen may be that they mis-labelled the specimens. *Rosellinia bothrina* was Thwaites 299, while the specimen assigned to *Rosellinia aquila* was Thwaites 219. It may be suggested that these numbers should have been reversed. But, in cases of this kind, where the type specimen differs from the description, it would seem essential that the type specimen, not the description, should decide the identity of the species. If it were held otherwise, mycologists would have to try to find species to fit descriptions which do not correspond with any fungus which ever existed.

Rosellinia bunodes (B. and Br.) Sacc.—This was originally described by Berkeley and Broome from Ceylon specimens. Its perithecia are rough with small warts, up to 0·1 mm. high, with a somewhat lozenge-shaped base, 0·2-0·4 mm. across. Its ascospores are 80-110 × 7-12 μ, with tips produced into a thread-like point which may be 25 μ long. It is apparently closely allied to *Rosellinia echinata* Massee, found on mango at Singapore, and to *Rosellinia Goliath* (Speg.) v. H. from South America (cf. *Ann. Perad.* iv. p. 434).

Ustulina zonata Lév.—This species was originally described from Java. Specimens sent from Ceylon about 1870 were referred by Berkeley and Broome to the European species, *Ustulina vulgaris* Tul., which it closely resembles. The zonation is due to periodic stoppages of growth and is not a constant feature. On an even surface, the mature stroma may be up to 9·5 cm. long, 4 cm. broad, and only 3 mm. thick in the centre. von Höhnel, who collected specimens in Java in 1907–1908, stated that it had a *Graphium* conidial stage,

but its development has been watched on numerous occasions in Ceylon, and in that country the stroma is always conidial at first, bearing, in the white stage, hyaline conidia on closely packed basidia over the whole surface (cf. *Ann. Perad.* v. p. 286). It was first observed to be parasitic in Ceylon.

Sphaerostilbe repens B. and Br.—This was first recorded from Ceylon in 1873, the specimens occurring on jak (*Artocarpus integrifolia*). It has since been found to attack arrowroot, papaw, *Hevea brasiliensis*, and cacao. The old name is here retained for it, but strictly it should be referred to *Corallomyces*, as *Corallomyces repens*. It is closely allied to the type species of the genus *Corallomyces*, *Corallomyces elegans* B. and C., from the West Indies, which similarly attacks cacao. It has been found growing as a saprophyte on chips of jak wood, and on felled dadap logs. In the latter case, the mycelium formed a continuous sheet between the wood and the bark, bordered by a network of advancing rhizomorphs. The conidia are remarkable for their great variation in size, from 9×6 to $22 \times 10\ \mu$. Conidia sown on the cut surface of a rhizome of arrowroot in a damp chamber developed the conidial stage in seven days and the perithecia in twenty-one days. The rhizomorphs are from 2 mm. to 1 cm. broad, and 0·5 to 2 mm. thick, red-brown, flattened, sometimes fusing into a continuous sheet; they are marked on both surfaces by an almost continuous median groove, and short, oblique, lateral grooves. Internally they are white, and composed of loosely interwoven hyphae, 4-8 μ in diameter. The cortex is up to 100 μ thick, and consists of four to six layers of rounded or polygonal cells, 10-15 μ diameter.

Botryodiplodia Theobromae Pat. –A discussion of the synonyms of this species was published in the *Annals of the Royal Botanic Gardens, Peradeniya*, iv. pp. 445-465 (1910), in a paper entitled "On *Lasiodiplodia*." Among its numerous synonyms are *Diplodia cacaoicola* P. Henn., *Lasiodiplodia nigra* Appel and Laub., *Macrophoma vestita* Prill. and Del., *Botryodiplodia elasticae* Petch, *Chaetodiplodia grisea* Petch, *Diplodia rapax* Massee. *Diplodia vasinfecta* is apparently *nomen nudum*; it was published by Watt and Mann, *Pests and Blights of the Tea Plant*, 2nd ed. (1903), p. 414, as a marginal reference.

The white fringe which appears round small clumps of hyphae or extruded spores on the roots consists of masses of minute, globose, hyaline spores, 1 μ diameter, with hyaline hyphae 1-2 μ diameter, on which the conidia are borne laterally, or on finer lateral branches. Whether this is a stage of the *Botryodiplodia* or a hyphomycete parasitic on the latter has not been determined.

This fungus is widely distributed, but in general is saprophytic. It is found on dead *Hevea*, cacao, *Castilloa*, *Albizzia*, dadap, papaw, *Ficus*, sugar cane, coconut, etc. In *Hevea*, it is the species which causes the principal damage in "die-back," and it sometimes kills stumps shortly after they are planted out.

Poria hypolateritia Berk.—This was originally described by Cooke

from specimens from South India in Berkeley's herbarium. The type specimen is very poor, and probably for that reason the name was not published by Berkeley, but it appears to be identical with the Ceylon species for which the name has been adopted. When sent from Ceylon by Thwaites it was assigned to an American species, *Polyporus vinctus* Berk.

Poria hypobrunnea Petch.—This was found to be parasitic on *Hevea* in 1905, and was then recorded as *Poria vincta* Berk., from a comparison with the Thwaites's specimens in the Peradeniya Herbarium. Thwaites included two species under his number 208, the one sent to Kew being *Poria hypolateritia* and the one retained at Peradeniya *Poria hypobrunnea*. The Kew specimen was assigned to *Polyporus vinctus*, and hence the same name was attached to the Peradeniya specimen. *Poria hypobrunnea* is common on *Hevea*, but appears to be rare on tea.

Fomes lamaoensis Murr.—Cunningham's description (1887) of the tea root disease examined by him leaves no doubt that he was dealing with Brown Root disease. On keeping affected roots in a damp chamber, they developed a green mould, but he was unable to determine whether that was connected with the brown mycelium. Zimmermann (1904) described the same disease in Java, and similarly obtained a green mould which he named *Sporotrichum radicicolum*; he did not consider it probable that the *Sporotrichum* was related to the brown fungus. In Ceylon, a similar green fungus which develops on roots attacked by Brown Root disease is the conidial stage of a *Hypocrea* which grows on other fungi, either *Basidiomycetae* or *Pyrenomycetae*. Zimmermann may be said to have originated the name Brown Root disease, as he called the fungus the Brown Root fungus. In 1905, the disease was discovered on *Hevea* in Ceylon and was recorded in the *Annual Report of the Mycologist* as probably identical with the *Hymenochaete* found on cacao in Samoa.

Specimens of the fungus which causes the Samoan disease were sent to Berkeley in 1875 with the information that it did great damage to bread-fruit trees. Berkeley did not publish any description of the species, nor did he label the specimens with any name, but in his MS. catalogue of his herbarium he inserted the name *Hymenochaete noxia* opposite the number of the specimen. Cooke published the name without description in *Grevillea*, viii. p. 149, stating at the same time that the fungus had no setae, and should be excluded from *Hymenochaete*! Thus, the name was *nomen nudum*, and admittedly incorrect. Subsequently, Massee (*Jour. Linn. Soc.* xxviii. p. 108) described it as *Hymenochaete toxia* (*sic*), stating that the setae are $40\text{-}70 \times 5\text{-}7\ \mu$.

The type of *Hymenochaete noxia* in Herb. Kew consists of mycelium only, in large thin pads, up to 2·5 mm. thick. The bulk of the pad is yellow-brown, somewhat spongy, and consists of interwoven, yellow-brown hyphae, generally 3-4 μ diameter, but sometimes 11 μ

diameter, flexuose, sparingly septate, with walls slightly thickened. This is covered by a thin, brittle, black crust, about 0·03 mm. thick, which is clothed with a thin, byssoid, red-brown layer of hyphae similar to the main mass, but sometimes straighter and with thinner walls, and sometimes terminating in an irregular point. Here and there the surface appears more velvety, and these velvety patches bear erect, thick-walled hyphae, dark yellow-brown, with pointed or obtuse tips, simple or branched above, up to 150 μ long; these hyphae resemble *Hymenochaete* setae.

The general structure of the type of *Hymenochaete noxia* resembles that of the mycelium on roots attacked by Brown Root disease, but it is a much larger development than anything yet observed in the latter. It does not include earth or stones, and apparently must have grown clear of the ground.

About 1895, specimens on cacao from Samoa were submitted to Hennings, who referred them, doubtfully, to *Hymenochaete leonina* B. and C. In 1907, Preuss recorded it again from Samoa, and referred it to *Hymenochaete noxia* Berk., apparently on the authority of Hennings. It has since been recorded under the same name from the Federated Malay States, Java, and West Africa.

That the fructification of the Brown Root disease of Ceylon is a *Fomes* was determined in 1917, and since that year it has been repeatedly verified. The identification of the *Fomes* as *Fomes lamaoensis* Murr. is due to Mr. C. G. Lloyd. Whether the Brown Root diseases of other countries are caused by the same fungus can be finally decided only by the discovery of the fructification in each case. The tissue of the pileus of *Fomes lamaoensis* is composed of hyphae of two kinds, the one thin-walled and yellow-brown, and the other thick-walled and more deeply coloured, like the setae of a *Hymenochaete*. This probably accounts for the occurrence of apparent setae among the mycelium of this species.

The apparent *Hymenochaete* fructifications which occur at the collar of plants attacked are usually small flat plates composed of interwoven hyphae with a few projecting setae. The powdery brown patches, which are sometimes found on the black crust on the roots, consist of branched hyphae, resembling conidiophores, and bearing minute brownish-yellow globules.

Fomes lignosus Klotzsch.—This species was originally found in Mauritius. When it first was recognised as a parasite, on rubber, it was referred to *Fomes semitostus* Berk., and that name has been used in most of the literature relating to it. *Fomes semitostus* is a different species, which was described by Berkeley from India in 1854, and has not been identified since. In 1898, however, Massee identified a fungus from Singapore as *Fomes semitostus*, and Ridley applied the name to the rubber root disease species. That identification was accepted until queried by Lloyd, who found that the rubber fungus was not *Fomes semitostus*, but *Fomes lignosus*. The type of

the latter is at Upsala. Lloyd published his finding in November 1912, but as far as publication of the combination *Fomes lignosus* is concerned he was antedated by Bresadola in the previous month. According to Lloyd, *Fomes Auberianus*, *Fomes contractus*, and *Fomes Kamphoveneri* are synonyms of *Fomes lignosus*.

Fomes lucidus (Leys.) Fr.—The appearance of roots attacked by *Fomes lucidus* in Ceylon, *e.g.* those of *Limonia alata*, differs considerably from that described. No external strands of mycelium were found on the root, the bark of which was in places blackened and bore minute white nodules composed of hyphae. Between the bark and the wood there was a thin white layer of mycelium, and the wood was filled with white hyphae. The diseased wood readily split into concentric sheets, and in some places these sheets were separated by thin, red films which turned pale brown when dry.

Polyporus interruptus B. and Br.—The cords of the Thread Blights are composed chiefly of very thick-walled or solid hyphae, and are thereby distinguished from the mycelium of *Polyporus interruptus*, in which the hyphae are normal in structure.

Irpex subvinosus (B. and Br.) Petch.—This was originally described from Ceylon by Berkeley and Broome as *Hydnum subvinosum*. The name was based on the colour of the dried specimen.

Armillaria mellea Vahl.—It would appear most probable that the Javan species is identical with the Ceylon *Armillaria fuscipes*.

Rhizoctonia sp. (p. 178).—The hyphae form a network on the rootlets, and are yellow-brown, regular, about 6 μ diameter, thick-walled.

CHAPTER VIII

FUNGI ON THE TEA BUSH

Basidiomycetae

Armillaria mellea Vahl.—Clustered. Pileus up to 12 cm. diameter, hemispherical, then nearly plane, centre depressed or slightly umbonate, dull yellow or brownish yellow, sprinkled with minute, spreading, black-brown scales, margin striate; flesh thin, except in the centre. Stalk up to 20 cm. high, 1 cm. diameter, usually thickened at the base, dingy ochraceous, floccose, stuffed, then hollow; ring spreading, large. Gills rather distant, narrow, adnate or slightly decurrent, whitish, becoming reddish. Spores white, elliptical, $9 \times 5\text{-}6\ \mu$.

Armillaria fuscipes Petch.—Clustered. Pileus up to 6 cm. diameter, broadly convex, then plane, obtusely umbonate, margin recurved, brown or yellow-brown in the centre, becoming white towards the margin, bearing minute, distant, brown warts in the centre; flesh thin, white, becoming brownish when cut. Stalk up to 10 cm. long, 9 mm. diameter at the base, attenuated upwards, blackish brown, floccose, becoming paler upwards, longitudinally striate and reddish above the ring, solid; ring ample, dependent. Gills white, rather crowded, narrow, attenuated outwards, decurrent. Spores white, oval or globose, smooth, $6\text{-}8 \times 5\text{-}7\ \mu$. Rhizomorphs red, becoming black.

Marasmius equicrinis Mull.—Pileus up to 8 mm. diameter, hemispherical, umbilicate, deeply radially sulcate, somewhat membranous, yellow-brown, red-brown, or ochraceous, with a minute black umbo at the base of the umbilicus; gills distant, five to eight, white then cream-coloured, broad, attenuated behind, united into a collar round the stalk; stalk black, shining, up to 2 cm. long, 0·25 mm. diameter, insititious, or arising from black, shining, rhizomorphic mycelium; spores white, narrow-oval, inequilateral, or clavate, $10\text{-}14 \times 4\ \mu$.

Marasmius pulcher (B. and Br.) Petch.—Sessile, resupinate or laterally attached, or shortly stalked, reniform or orbicular, up to 2·5 mm. diameter, white, convex, sulcate over the gills, minutely pruinose, lower surface and gills ochraceous. Gills few, sometimes forked, one to three extending from the point of attachment to the margin, with three or four shorter. Spores white, cymbiform, $6\text{-}8 \times 4\ \mu$.

Polyporus interruptus B. and Br.—Effused, forming thin, indefinite, white sheets with a narrow, white, tomentose margin, sometimes producing small white brackets, up to 3 cm. long, 1 cm. broad, at the upper edge. Upper surface of the brackets white, tomentose, or radially fibrillose. Pores soft, watery, with thick dissepiments which become thin on drying, minute, angular when dry, up to 2 mm. long. Basal layer of the resupinate form a thin weft of hyphae, almost absent.

Polyporus mesotalpae Lloyd.—Centrally stalked, with a thick stem. Stem up to 10 cm. high and 6 cm. diameter; pileus up to 40×20 cm., and 10 cm. thick, usually tuberculate and lobed, depressed in the centre, sometimes turbinate. At first white, becoming deep chocolate; surface minutely velvety, with a thin, black, crustaceous layer beneath. Stalk deep chocolate-brown, minutely velvety, becoming glabrous, black, and carbonaceous when old. Context white and watery when fresh, turning red when cut; when dry, brownish grey, soft and spongy, radially floccoso-fibrillose. The whole fungus turns blackish brown if handled in the white stage. Pores minute, watery when fresh, forming a distinct layer, about 2 mm. deep.

Poria hypolateritia Berk.—Effused, pinkish or pale red, with a white tomentose margin at first. Internally white, the extreme basal layer red or red-brown, horny. Pores medium, up to 0·2 mm. diameter, angular, dissepiments thin. Total thickness about 1 mm.

Poria hypobrunnea Petch.—Effused, at first pale ochraceous, then pinkish red, becoming brownish red, and finally slate-coloured; margin at first white, tomentose. Basal layer blackish brown, stout and compact when developed on a level surface, but loose and woolly when on an irregular surface or on soil. Thickness of the compact form about 1·5 mm. Pores small, 0·1 mm. diameter.

Fomes applanatus Pers.—Bracket-shaped, flat or slightly convex, usually up to a foot in diameter, brown with grey zones, not polished, the upper layer forming a hard crust; lower surface white; in section, dark brown, fibrous above, with a thick layer of long tubes below.

Fomes lucidus (Leys.) Fr.—Bracket-shaped, several inches in diameter and about an inch thick; upper surface at first red or red-brown behind, with a white margin and an intermediate yellow zone, becoming entirely red or red-brown or chestnut, lacquered, shining; lower surface white, usually with a shining, deep red, or almost black zone along the line of attachment to the host plant; internally brown.

Fomes lamaoensis Murrill.—Bracket-shaped, rather thin, hard, frequently concentrically grooved, purple-brown, glabrous, with a hard outer crust; internally rather light yellow-brown, often with concentric growth zones, composed of two kinds of hyphae, the one thin-walled, the other thick-walled and resembling the setae. Pore surface dark brown or purple-brown; pores minute; setae numerous, obtuse; spores hyaline.

Fomes lignosus Klotzsch.—Bracket-shaped, woody, imbricated;

pileus dimidiate, large, red-brown with a yellow margin at first, becoming pale yellow-brown with concentric dark brown lines, smooth, feebly sulcate, slightly silky with adpressed fibrils; pore surface orange, becoming red-brown when old; context white, pore layer red-brown in section; pores minute, 0·06-0·12 mm. diameter, 2·5-3·5 mm. long.

Trametes Theae Zimm.—Adnate, thin, irregularly circular, flat, sordid yellow, margin sterile; pores rounded, 0·15 mm. diameter.

Corticium salmonicolor B. and Br.—Thin, effused, frequently surrounding stems and branches for a considerable distance, rose-pink or ochraceous, minutely pulverulent, finally cracked and areolated; basidia clavate, tetrasporous; sterigmata slender, 4-6 μ long; spores pyriform, hyaline, apiculate, 9-12 $\times$ 6-7 μ.

Corticium Theae Bernard.—Rhizomorphs pinkish, more or less branched and anastomosing, on branches; hymenium on the under surface of the leaves, pulverulent. Basidia 20-25 $\times$ 6-8 μ, not crowded; spores elliptic, hyaline, smooth, 7-9 $\times$ 5-7 μ.

Irpex destruens Petch.—Dimidiate, resupinate behind, often imbricated. Pilei orbicular, elongated, or flabelliform, up to 2 cm. wide, thin, coriaceous. Upper surface red-brown to ochraceous, often zoned when moist, minutely tomentose, radially fasciato-rugose; context white or pale yellow; hymenium pale ochraceous; aculei up to 4 mm. long, triangular, flattened. *Irpex zonatus* Berk., in Fungi of Ceylon, No. 553.

Irpex subvinosus (B. and Br.) Petch.—Resupinate. Lavender, or blue, with a white margin, becoming grey, then pale brown, when old. Sterile margin usually broad, fimbriate. Teeth terete, or more usually flattened, up to 4 mm. long, appearing tomentose. Basal layer woolly, appearing powdery; hyphae with free clavate ends. Basidia short, clavate, about 15 μ long. Cystidia scanty, oval or flask-shaped, sometimes constricted towards the apex, slightly longer than the basidia.

Exobasidium vexans Mass.—Spots concave on the upper surface, convex below; hymenium chiefly hypophyllous, white, tomentose. Conidia one-septate, hyaline, 12-21 $\times$ 4·5-6 μ, narrow-oval, solitary; conidiophores simple. Basidia clavate, 30-90 $\times$ 3·7-6 μ, two-spored; spores hyaline, elliptical, continuous, 7-13·6 $\times$ 2·3-4·5 μ.

Exobasidium reticulatum Ito and Sawada.—Spots scattered, diffuse, 2-3 cm. diameter, yellowish, then brown to dark brown, finally drying and shrinking. Hymenium hypophyllous, reticulated, white. Basidia cylindrico-clavate, 4-spored, 100-135 $\times$ 3-4 μ. Basidiospores oblong-ovate, straight or slightly curved, hyaline, continuous, 9-12 $\times$ 3-3·5 μ. Two-celled basidiospores also present.

Septobasidium Acaciae Sawada.—Filamentous, rigid, effused, 10 cm. across, 70-180 μ thick; surface smooth, brown or tobacco brown when dry, brownish when wet; margin greyish white; hyphae yellowish brown when mature, 3 μ diameter; protobasidia spherical,

hyaline, subsessile, finely guttulate, 9-15 μ; basidia easily detached, cylindric, truncate below, subacute above, straight or slightly curved, hyaline, 1-5-septate, 52-81 × 4-6 μ; sterigmata 4-12 μ long; spores hyaline, oblong to obovoid, curved, 18-22 × 3-6 μ, germinating with short tubes and producing sporidia similar to the basidiospores, 11-15 × 3-5 μ.

Helicobasidium Tanakae Miyabe.—Up to 10 cm. diameter, flat, lichenous, 1 mm. thick, surface velvety, brownish, pale purple-brown, or dark brown, with a narrow, thin, greyish margin; hyphae amber-coloured, thick-walled, 3-5 μ diameter; protobasidia not formed; basidia at first clavate, unicellular, hyaline, but when mature subfusoid, 2-4-septate, straight or curved, 49-65 × 8-9 μ; sterigmata long, curved, 35-63 × 3·5-4 μ, apical from the terminal cell, lateral from the others; spores hyaline, continuous, long-falcate, obtuse, 27-40 × 4-6 μ, producing hyphae on germination.

Pyrenomycetae

Protomyces Theae Zimm.—Mycelium thick-walled, external and internal. Asci within the root, usually in groups, lateral or terminal, irregularly globose, 0·14-0·22 mm. diameter, thick-walled, yellow; spores not seen.

Zukalia Theae Saw.—Perithecia black, globose, 67-135 μ diameter; subiculum black, hyphae at first pale, later brownish, 3-6 μ diameter; perithecia numerous, surrounded by 6-9 dark brown, blunt, 3-6-septate setae, 70-100 × 4 μ; asci 8-spored, clavate, fusiform, 68-90 × 13-16 μ; spores hyaline, obovate-elliptic to clavate, three-septate, 17-23 × 6-7 μ.

Zukalia nantoensis Saw.—Epiphyllous, sometimes also hypophyllous, lichenous, spreading over an area 2-5 mm. broad, closely coalescent; hyphae fuliginous, thick-walled, 8 μ diameter, septate and sparsely furnished with hyphopodia, which are oblong, rounded at the apex, usually on a stalk 18-25 μ long. Pycnidia and perithecia orbicular, black, generally sessile, sometimes on stalks 18-25 μ long; pycnidia 63-95 μ, containing numerous pycnospores; pycnospores pale brown, ellipsoid to oblong, smooth, continuous, two-guttulate, 6-8 × 3-4 μ; perithecia 132-180 μ diameter, with numerous asci; asci oblong-clavate or ovoid-oblong, shortly pedicellate, eight-spored, 33-49 × 10-12 μ; ascospores oblong to subclavate, medially one-septate, hyaline, ends obtuse or truncate, 9-13 × 3·5-5 μ.

Limacinula Theae Syd. and Butl.—Mycelium black, effused, crustaceo-membranaceous, generally covering the upper surface of the leaf, composed of septate, fuscous hyphae, some repent, about 5 μ diameter, and furnished with simple, acute, black setae, up to 130 μ long and 8 μ diameter below, others erect, 10 μ diameter, and branched; conidia (*Triposporium*) stellately four-rayed; pycnidia erect, dimorphic, some up to 300 μ high, cylindric, inflated in the middle to 22 μ diameter, attenuated above, others broadly cylindric,

about 80 μ high and 30 μ diameter; pycnospores cylindric, straight, hyaline, continuous, 2·5-3 × 1·5 μ; perithecia superficial, globose then depressed, ostiolate, 150-225 μ diameter; asci subsessile, ovoid, eight-spored; spores oblong, ends rounded, hyaline, muriform, generally with five transverse septa and one longitudinal, 25-33 × 9-11 μ.

Scorias capitata Saw.—Mycelium black, on the upper surface of the leaves, sometimes on the lower surfaces and twigs. Perithecial stalks black, once or twice branched, usually conical, cylindric, fusiform or elliptic, 110-247 × 52-75 μ, constricted at the apex and terminated by perithecia; perithecia black, nearly ovate or orbicular, 60-83 × 50-78 μ, containing numerous asci; asci clavate, obtuse, 30-35 × 9-12 μ, six- or eight-spored; spores fusiform, to clavate-fusiform, obtuse, hyaline, three-septate, 10-11·5 × 3-3·5 μ.

Asterina Camelliae Syd. and Butl.—Perithecia epiphyllous, membranous, scutate, composed of radiating hyphae, dehiscing stellately, 200-300 μ diameter, clustered and confluent in groups and forming black crusts up to 1 cm. wide; asci few, elliptico-obovate, eight-spored, 70-100 × 25-35 μ; spores ellipsoid, ends rounded, centrally one-septate, constricted at the septum, brown, 30-33 × 16 μ.

Guignardia Camelliae (Cooke) Butler = *Laestadia Theae* Rac.—Spots large, rounded, brown, becoming grey; perithecia globose, immersed, black, amphigenous, up to 250 μ diameter; asci elongate-elliptic, 40-50 × 8-9 μ, eight-spored; spores elliptic, hyaline, continuous, 8-18 × 3·5-5 μ.

Desmotascus neglectus Petch (= *Physalospora neglecta* Petch).—Stromata about 0·3 mm. diameter, black, globose, gregarious, immersed; ostiolum papillate, 0·08 mm. diameter, 0·08-0·12 mm. high, projecting; asci embedded in hyaline parenchymatous tissue, 140-160 × 35 μ, clavate, thick-walled at first, eight-spored, spores biseriate; spores hyaline, thick-walled, inequilateral, cymbiform, 32-40 × 12-16 μ.

Rosellinia arcuata Petch.—Perithecia gregarious, at first embedded in purple-brown mycelium, black, superficial, globose, slightly depressed, 1·5-2·4 mm. diameter, smooth; ostiolum conical, 0·1 mm. high, 0·4 mm. diameter at the base. Asci about 300 × 8 μ, cylindric, eight-spored, spores obliquely uniseriate; paraphyses filiform, 2 μ diameter, as long as the ascus. Spores black, cymbiform, ends pointed and often abruptly narrowed, 40-47 × 5-7 μ. Conidiophores erect, up to 2 mm. high, 0·1 mm. diameter, black, compound, of the Graphium type; conidia hyaline, narrow-oval, 4-6 × 2 μ.

Rosellinia bunodes B. and Br.—Perithecia gregarious, embedded at first in purple-brown mycelium, superficial, brownish-black, globose, up to 1·6 mm. diameter, verrucose with close-set pyramidal warts; ostiolum sometimes papillate, sometimes not elevated. Spores cymbiform or lanceolate, ends acute and produced into a thread-like point up to 25 μ long, black-brown, 80-110 × 7-12 μ.

Mycosphaerella Theae K. Hara.—Spots orbicular or irregularly circular, 3-4 mm. diameter, finally confluent, dark brown, becoming

grey; perithecia epiphyllous, immersed, ostiolum finally erumpent, gregarious, black, globose or depressed globose, 50-150 μ diameter; wall carbonaceous, parenchymatous, of polygonal cells, 3-8 μ broad; ostiolum papillate; asci cylindrico-clavate or oblong-ovoid, eight-spored, pedicellate, 30-42 × 6-8 μ; ascospores biseriate, cylindric or oblong-ovoid, ends subobtuse, one-septate, not constricted, the upper cell the broader and shorter, hyaline, 10-13 × 2-2·5 μ. Parasitic on leaves of tea, Japan.

Spots first appear on the surface of the leaves as small, round, dark-coloured areas 1 mm. across, which gradually enlarge forming irregular patches 3-4 mm. in diameter, and later becoming confluent, forming large, irregular, dead areas extending towards the leaf margin. Such areas are dark-coloured brownish grey and develop abundant black minute specks on the upper surface, while the lower surface remains a dark brown colour.

Mycosphaerella Ikedai K. Hara.—Perithecia amphigenous, usually hypophyllous, scattered or gregarious, immersed, globose or depressed globose, 50-80 μ diameter, wall parenchymatous of cells 5-8 μ broad, carbonaceous, ostiolum papillate or simple; asci obovoid or oblong, pedicellate or sessile, eight-spored, 40-45 × 8-12 μ; ascospores tri-seriate or irregularly polyseriate, oblong-ovoid or cylindric, one-septate, deeply constricted, the upper cell usually the broader and shorter, hyaline, 13-16 × 5-5·5 μ. On leaves of tea; saprophytic, Japan.

Venturia Speschnewii Sacc. (=*Coleroa venturioides* Spesch.).—Perithecia gregarious, subglobose, cupuliform, ochraceous, at first subepidermal, then subsuperficial, epiphyllous, 100-130 μ diameter, 50-80 μ high, clothed with flexuose, septate, fuliginous setae, 50-60 × 5-6 μ. Asci clavate, 30-40 × 8-10 μ, eight-spored. No paraphyses. Spores oblong-oval, pale greenish, 14 × 8 μ.

Phaeosphaerella Theae Petch.—Perithecia immersed, epiphyllous, black, minute, 80-100 μ diameter; asci few, eight-spored, clavate, 50 × 12 μ; spores fusoid, one-septate, constricted at the septum, pale brown, the upper cell the larger and rounded at the apex, the lower somewhat oblong and obtuse at the apex, 9-14 × 4-5 μ.

Massaria theicola Petch.—Perithecia gregarious, immersed, black, 0·25-0·3 mm. diameter; asci narrow-cylindric, eight-spored, spores obliquely uniseriate, 120-160 × 20 μ; paraphyses few, septate; spores narrow-oval, two-septate, olivaceous, the central cell darker than the terminal cells, 17-22 × 6 μ.

Pleospora Theae Speschnew.—Perithecia (?). Ascospores biseriate, dark brown, with two to three or more transverse septa and two longitudinal septa, 24-28 × 8-10 μ. Conidial stage, *Macrosporium commune* Rabh. var. *theicolum* Speschnew,—conidiophores clustered, radiating, 50-90 μ high, 3-4 μ diameter; conidia muriform, 24-28 × 10 μ.

Ustulina zonata Lév.—Stroma effused, undulating, centrally attached, often concentrically zoned, thin, several centimetres in

diameter; at first white, bearing crowded, simple conidiophores in a continuous stratum, with narrow-oval, hyaline conidia, 6-8 × 2-3 μ; becoming greenish, then purple-grey, dotted with black ostiola, finally black and brittle. Perithecia globose, about 1 mm. diameter, distant, ostiola scarcely projecting; asci cylindric, long-stalked, eight-spored, 250 × 10 μ; spores black-brown, cymbiform, ends obtuse, 30-38 × 9-13 μ.

Aglaospora aculeata Petch.—Perithecia immersed in the cortex, in a stroma composed of hyphae and cortical tissues bounded above by a black line, in groups of about six, confluent, with a common ostiolum; perithecial cavities depressed, up to 1 mm. diameter, 0·4 mm. high; ostiolum conical or subcylindric, projecting 0·75-1·5 mm. above the surface. The outer layers of the cortex crack, and sometimes fall off, exposing a black, pulvinate, carbonaceous stroma, 3-5 mm. diameter. Asci cylindric, narrow above, apex truncate, pedicel curved, four-spored, 180-210 × 30-35 μ; spores cymbiform, fuliginous, 7-11-septate, 90-105 × 12-15 μ.

Nectria cinnabarina (Tode) Fr.—Perithecia clustered, on a pulvinate, fleshy stroma, which first produces conidia, spherical, rough, cinnabar, ostiolum papillate; asci cylindrico-clavate, attenuated above, eight-spored, 60-90 × 8-12 μ; ascospores oblong, obtuse, straight or slightly curved, uniseptate, hyaline, 14-16 × 5-7 μ.

Nectria cancri Rutgers.—Perithecia 0·4-0·5 mm. high, 0·3-0·4 mm. diameter, orange-red, rough, scattered or clustered, without a stroma; asci 90 × 6 μ, eight-spored, spores uniseriate; spores oval or oblong-oval, ends rounded, constricted at the septum, 10-13 × 3-5 μ.

Sphaerostilbe repens B. and Br.—Conidiophores 2-8 mm. high, 0·5-1 mm. diameter; stalk red-brown, tomentose with spinulose hairs; conidia oval, hyaline, continuous, 9-22 × 6-10 μ. Perithecia clustered, dark red, flask-shaped, 0·6 mm. high, 0·4 mm. diameter; asci cylindric, eight-spored, spores uniseriate, 190-220 × 9 μ; spores oval, one-septate, slightly constricted, pale brown or reddish brown, 19-21 × 8 μ.

Sphaerioidaceae

Phyllosticta Theae Speschnew.—Pycnidia scattered, lenticular, strongly depressed, 100-240 μ diameter, 60-80 μ high. Spores hyaline, oblong-elliptic, obsoletely biguttulate, 6-8 × 1·5-2 μ.

Phoma Camilleae Cooke.—Hypophyllous. Pycnidia scattered, minute, membranaceous, scarcely 0·1 mm. diameter, opening by a pore: spores elliptic, biguttulate, 10 × 5 μ. On leaves of tea with *Guignardia Camelliae.*

Phoma theicola Petch.—Leaf spot red-brown. Pycnidia amphigenous, scattered, immersed, 0·1 mm. diameter, ostiolum 16 μ diameter. Spores broadly oval, hyaline, 8-10 × 5-6 μ.

Macrophoma Theae Speschnew.—Pycnidia scattered, parenchymatous, fuliginous, at first covered by the epidermis, then erumpent

and almost free, 60-140 μ. Spores oblong-ellipsoid, continuous, hyaline, contents granular, 16-18 $\times$ 3-4 μ. Basidia filiform, short, inconspicuous.

Macrophoma theicola Petch.—Pycnidia immersed, scattered or clustered, elevating and cracking the outer layers of the cortex irregularly when mature, up to 0·25 mm. diameter, black, thin-walled; ostiolum 16-25 μ diameter, not projecting; spores narrow-oval or fusoid, ends obtuse or subtruncate, hyaline, continuous, 27-32 $\times$ 5-7 μ.

Chaetophoma Penzigi Sacc. var. *theicola* Speschnew.—Pycnidia dark brown, leathery, globose, somewhat produced above, on a thick weft of greyish olive mycelium, clothed with stout, dark chestnut-coloured setae, 60-70 μ long. Pycnospores hyaline, cylindric with rounded ends, one-septate (*ex* Speschnew's figure), 8-14 $\times$ 2-3 μ.

Neottiospora Theae Sawada.—Spots epiphyllous, irregular, ashy to brown; margin definite, elevated, purplish black; pycnidia scattered, subepidermal, black, depressed globose to spheroid, 84-93 $\times$ 108-135 μ, ostiolum erumpent; spores cylindric, hyaline, continuous, ends rounded or obtuse, ciliate at one end, 12-14 $\times$ 3 μ: setae filamentous, 9-11 μ long. Occurs rarely on mature leaves in Formosa, and does not appear to cause serious damage.

Botryodiplodia Theobromae Pat.—Pycnidia immersed, scattered or clustered, or in erumpent glabrous or villous stromata, globose, 0·25-0·4 mm. diameter. Paraphyses numerous, linear, up to 80 μ long. Spores oval, one-septate, fuliginous to black or black-brown, 24-30 $\times$ 12-15 μ.

Stagnospora theicola Petch.—Pycnidia minute, gregarious, immersed, black, about 0·1 mm. diameter; spores three-septate, greenish hyaline, oblong, ends rounded, straight or slightly curved, 15-17 $\times$ 5 μ. On leaves of tea, with *Guignardia Camelliae* (Cke.) Butler and *Colletotrichum Camelliae* Mass.

Hendersonia theicola Cooke.—Pycnidia globose, black, prominent, ostiolate, scattered or subgregarious, amphigenous; spores cylindric, ends rounded, triseptate, pale brown, the terminal cells sometimes paler, 10-12·5 μ long, on long, hyaline pedicels.

Septoria Theae Cav.—Pycnidia widely open when mature; spores cylindric, obscurely septate, flexuose, faintly coloured, 60-90 $\times$ 2 μ.

Piggotia Theae New.—Spots dry, irregular, marginal, visible on both sides of the leaf, bounded on the upper by a black line. Pycnidia amphigenous, moderately clustered, black, dehiscing irregularly, thin-walled, parenchymatous, 78 μ diameter. Spores cylindric, straight, ends rounded, subtruncate, bluish green, 15-13 $\times$ 2 μ.

Discosia Theae Cav.—Pycnidia scattered, superficial, flattened, black, rugulose, ostiolum prominent. Spores cylindric, slightly curved, obtuse, obliquely uniciliate at each end, three-septate, terminal loculi hyaline, median loculi greenish, 18-20 $\times$ 2-3 μ, setae 6-8 μ.

Melanconiaceae

Gloeosporium Theae-sinensis Miyake.—Acervuli epiphyllous, scattered, black, subepidermal then erumpent, 80-120 μ diameter; basidia hyaline, short, linear, $10\text{-}16 \times 1\text{-}1{\cdot}5$ μ; spores hyaline, fusoid or oval, ends acute, usually biguttulate, $4\text{-}6 \times 2$ μ.

Gloeosporium Theae Zimm.—Acervuli amphigenous, up to 90 μ diameter; spores hyaline, cylindric, ends obtuse, continuous, $14\text{-}19 \times 4\text{-}6$ μ.

Colletotrichum Camelliae Massee.—Spots at first yellowish green, then red-brown or dark brown, sometimes mottled, with a yellow-green margin. Acervuli amphigenous, pinkish; conidia cylindric, ends obtuse, hyaline, continuous, $10\text{-}18 \times 4\text{-}5$ μ; setae black-brown, septate, from 36×4 to $135 \times 7\text{-}8$ μ.

Colletotrichum Carveri Ell. and Ev.—Spots brown; acervuli epiphyllous, erumpent, yellowish, 250-500 μ diameter; setae generally few, arising from the base of the acervulus, brown, continuous, curved, slightly thickened at the base, $40\text{-}80 \times 3$ μ; conidia oblong-cylindric, $12\text{-}15 \times 3{\cdot}5\text{-}5$ μ, ends obtusely rounded.

Pestalozzia Theae Saw.—Acervuli erumpent; basidia simple, $4\text{-}9 \times 1$ μ; conidia fusiform, four-septate, slightly constricted, three inner cells dark brown, 16-21 μ, basal and apical cells hyaline, 4-6 μ, setae three or four, $28\text{-}36 \times 1\text{-}2$ μ, slightly swollen at the apices.

Hyphomycetae

Cercosporella Theae Petch.—Spots large, extending from the margin of the leaf, or circular, about 5 mm. diameter, grey or greyish white, bordered by a narrow purple-brown line, on the upper surface, greyish brown with a watery green border on the lower. Hyphae forming a thin white film on the lower surface on and round the spot, hyaline, 5 μ diameter, equal, sometimes united into strands; conidiophores simple or branched; conidia cylindric, or fusoid, sometimes inequilateral, ends obtuse or truncate, up to six-septate, not constricted, $64\text{-}130 \times 5\text{-}14$ μ.

Helminthosporium Theae Bern.—Conidiophores erect, deep brown, septate, $300\text{-}350 \times 10\text{-}12$ μ; conidia obclavate-pyriform, 3-4-septate, attenuated and acute above, the two lower loculi brown, the upper much narrower and subhyaline, $20\text{-}22 \times 7\text{-}8$ μ.

Fusicladium Theae K. Hara.—Acervuli amphigenous, velvety, black; conidiophores filiform, straight or curved, thickened at the base, continuous to three-septate, brownish below, pale and often crooked above, $40\text{-}70 \times 5$ μ; conidia terminal, occasionally lateral, cylindric or oblong-ovate, one-septate, usually not constricted, apex obtuse, base somewhat acute, straight or curved, hyaline or yellowish, $15\text{-}28 \times 5\text{-}6$ μ. On leaves of tea, Japan.

Cercospora Theae v. Breda de Haan.—Spots circular, at first black

or purple, sunken, becoming white with a swollen purple margin, membranous, small, up to 3 mm. diameter. Acervuli minute, black, on either side of the leaf. Conidia elongated, up to 140 μ long, 3-4 μ diameter, irregularly curved, hyaline, multiseptate.

Stilbum nanum Massee.—Total height, 0·75-1·2 mm. Stalk red, red-brown at the base, 50-80 μ diameter in the middle, 0·1 mm. diameter at the base, attenuated from the base to about two-thirds its height, then slightly expanding upwards, subtranslucent, almost smooth, covered with horizontally projecting, short, cylindric, irregularly bent cells, 8-12 μ long, 3-4 μ diameter. Head pink, globose, up to 0·3 mm. diameter. Conidia hyaline, narrow-oval, 4-6 $\times$ 2-2·5 μ (redescribed from the type specimen).

Stilbella Theae Bernard.—Stalk red, dark red-brown at the base, clear orange-red above, papillate, almost smooth, 300-800 μ high; head rose-coloured, more or less globose, 150-300 μ diameter; conidia hyaline, 5-7 $\times$ 2·5-4 μ. Probably identical with *Stilbum nanum* Mass.

Didymostilbe Coffeae P. Henn.—Total height, up to 0·8 mm. Stalk white, 30 μ diameter in the middle, almost equal, slightly expanded at the base and towards the apex; head red, globose or ovoid, subtranslucent, 50-100 μ diameter; conidia fusoid, sometimes inequilateral, sometimes attenuated towards either end, ends acute or obtuse, one end sometimes truncate, hyaline, one-septate, not constricted, 16-20 $\times$ 5-6 μ.

Mycelia Sterilia

Sclerotium zeylanicum (B. and Br.) Petch.—Sclerotia produced on fleecy, white, superficial patches of mycelium overrunning plants or soil, white, then pale ochraceous, or pinkish, finally brown, glabrous, globose, about 1 mm. diameter, internally white, hard, compact.

BIBLIOGRAPHY

ANDREWS, E. A., and TUNSTALL, A. C. Notes on the spraying of tea. Indian Tea Association, Bulletin No. 1, 1915.

ANNETT, H. E., and KAR, S. C. Amount of copper in tea sprayed with Bordeaux mixture. Journal of Agricultural Science, iii. pp. 314-316 (September 1910).

ANSTEAD, R. D., and MCRAE, W. Brown Blight of tea. Planters' Chronicle, xi. pp. 2-4 ; 639-641 (1916).

BERKELEY, M. J. [Thread Blight.] Gardener's Chronicle, 1873, No. 24, pp. 810, 811.

On the Thread Blight of tea. Quarterly Journal Microscopical Society, 1875, p. 130.

BERNARD, C. Notes de pathologie végétale, i. Bull. Dépt. Agric. Indes Néerlandaises, vi. (1907).

Grey Blight ; *Hypochnus Theae ; Laestadia Theae.*

Notes de pathologie végétale, ii. Bull. Dépt. Agric. Indes Néerlandaises, xi. (1907).

Stilbella Theae ; *Helminthosporium Theae ; Pestalozzia palmarum.*

Ziekten der Theeplant. Meded. van het Proefstation voor Thee, ii. (1908).

Root diseases ; diseases of seedlings ; branch canker, etc.

Observations sur le thé. Bull. Dépt. Agric. Indes Néerlandaises, xxiii. (1909).

Stilbella ; root diseases ; diseases of seedlings ; *Corticium salmonicolor* ; *Hypochnus Theae* ; grey fungus of dadaps ; Red Rust ; die-back of shoots ; leaf diseases.

Over eene ziekte der jonge thee planten. Meded. van het Proefstation voor Thee, ix. (1910).

Red Rust. Meded. van het Proefstation voor Thee, xxxii. (1914).

Over eenige ziekten en plagen van de thee op de Oostkust van Sumatra. Meded. van het Proefstation voor Thee, liv. (1917).

Root diseases.

Aanvullende mededeelingen over de wortelziekten van de thee. Meded. van het Proefstation voor Thee, lxi*a*. (1919).

BERNARD, C., and DEUSS, J. J. B. Over het teeren der snoeiwonden bij de thee. Meded. van het Proefstation voor Thee, xxv. (1913) : summarised under title, Tarring pruning-cuts on tea, in Tropical Agriculturist, xli. pp. 519-521 (December 1913).

BERNARD, C., and PALM, B. Over de door schimmels veroorzaakte wortelziekten van de thee plant. Meded. van het Proefstation voor Thee, lxi. (1918).

Poria hypolateritia ; Ustulina zonata ; Rosellinia arcuata ; Rosellinia bunodes ; Armillaria mellea ; Hymenochaete noxia.

BERNARD, C., and WELTER, H. L. Bibliographisch Overzicht. Meded. van het Proefstation voor Thee, i. (1908).

BREDA DE HAAN, J. VAN. Vorlaufige Beschreibung von Pilze bei tropischen Kulturpflanzen beobachtet. Bull. Inst. Bot. Buitenzorg, No. 6 (1900).

Cercospora Theae.

Carruthers, J. B. Reports of the Government Mycologist and Assistant Director, Royal Botanic Gardens, Ceylon, 1900, 1901, 1903, 1904.
Grey Blight: *Rosellinia* (1903, 1904); Horsehair Blight (1903); Branch canker (1903, 1904).
Root disease in tea. Circulars and Agricultural Journal of the Royal Botanic Gardens, Ceylon, vol. ii. No. 6 (July 1903).
Branch Canker in tea. Circulars and Agricultural Journal of the Royal Botanic Gardens, Ceylon, vol. ii. No. 28 (January 1905).
Collett, O. Notes of observations on some tea diseases. Tropical Agriculturist, xix. pp. 824, 825 (June 1900).
Grey Blight; Brown Blight; Red Rust.
Cooke, M. C. Blights on Tea and Cotton. Grevillea, i. p. 90 (1872).
Hendersonia theaecola.
Fungi of Perak. Grevillea, xiii. pp. 1-5 (1884).
Laestadia Camilleae Cke.; *Phoma Camilleae* Cke.
Cunningham, D. D. On a destructive blight in tea plants dependent on the invasion of the tissues of the roots by the mycelium of a fungus. Scientific Memoirs, Medical Officers of the Army of India, Pt. III. (1887), pp. 8-11.
On certain diseases of fungal or algal origin affecting economic plants in India. Scientific Memoirs, Medical Officers, Army of India, x. (1897), p. 95.
Red Rust; Thread Blight; Brown root disease.

Delacroix, G. Les Maladies du théier. Journal d'Agriculture tropicale, ii. 9, p. 67 (1902).
Delacroix, G., and Maublanc, A. Maladies des plantes cultivées dans les pays chauds. Paris, 1911.

Hope, G. D., and Carpenter, P. H. Report on disease in tea seed nurseries. Indian Tea Association, Bulletin No. 5 (1909).
Hori, S. A serious disease of tea caused by a new bacterium, *Bacillus Theae* Hori and Bokura, sp. nov. Journal of Plant Protection (Japanese), i. 247-252; ii. 1-7.

Indian Tea Association. Scientific Department. Quarterly Journal. Calcutta, 1911– .
Ito, S., and Sawada, K. A new Exobasidium disease of the tea plant. Botanical Magazine (Tokyo), xxvi. (Aug. 1912), pp. 236-241.

Kerkhoven, A. R. W. Eenige observaties betreffende de Red Rust op de theehesters. Meded. van het Proefstation voor Thee, xxxii. (1914).

Mann, H. H. The Blister Blight of tea. Indian Tea Association, Bulletin No. 3 (1906).
Mann, H. H., and Hutchinson, C. M. Red Rust; a serious blight of the tea plant. Indian Tea Association, Bulletin No. 4 (1904).
Cephaleuros virescens Kuntze, the Red Rust of tea. Memoirs, Dept. of Agriculture in India, Botanical Series, vol. i. No. VI.
Massee, G. Tea blights. Kew Bulletin, 1898, pp. 105-112.
Grey Blight; Blister Blight; Thread Blight.
Tea and Coffee diseases. Kew Bulletin, 1899, pp. 89-94.
Brown Blight.
McRae, W. Report on the outbreak of Blister Blight on tea in the Darjeeling district in 1908-1909. Bulletin No. 18, Agricultural Research Institute, Pusa, 1910.
The outbreak of Blister Blight on tea in the Darjeeling district in 1908–1909. Agricultural Journal of India, v. pp. 126-137 (1910); reprinted as Bulletin No. 32, Indian Tea Association (1910).

MIYAKE, I. Über einige Pilz-Krankheiten unserer Nutzpflanzen. Botanical Magazine (Tokyo), xxi. (1907), pp. 39-44.
Gloeosporium Theae-sinensis.

NEWODOWSKY, G. Pilzschädlinge der kultivierten und wildwachsenden Pflanzen des Kaukasus im Jahre 1911. Bull. Jard. Bot. Tiflis, xxxi. (1912). Also in *Mycoflorae Caucasicae novitates*, Moniteur Jard. Bot. Tiflis, xxi. (1912), p. 16.
Piggotia Theae New., on Tea.

PETCH, T. Descriptions of new Ceylon fungi. Annals, Royal Botanic Gardens, Peradeniya, iii. pp. 1-10 (May 1906).
Massaria theicola ; Aglaospora aculeata ; Staganospora theicola.

New Ceylon fungi. Annals, Royal Botanic Gardens, Peradeniya, iv. pp. 299-307 (March 1909).
Irpex destruens ; Physalospora neglecta.

Additions to Ceylon fungi. Annals, Royal Botanic Gardens, Peradeniya, vi. pp. 195-256 (July 1917).
Phaeosphaerella Theae ; Macrophoma theicola ; Cercosporella Theae.

Reports of the Government Mycologist, Ceylon, 1905–

A stem disease of tea. Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, vol. iv. No. 4 (1907).
Massaria theicola Petch.

A bark disease of *Hevea*, tea, etc. Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, vol. iv. No. 21 (1909).
Corticium salmonicolor B. and Br.

Brown root disease. Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, vol. v. No. 6 (1910).

Root diseases of tea. Circulars and Agricultural Journal, Royal Botanic Gardens, Ceylon, vol. v. No. 11 (1910).

Mycological Notes. Tropical Agriculturist, xxiv. pp. 103, 104 (May 1905).
Branch canker of tea.

Mycological Notes. Tropical Agriculturist, xxv. pp. 298, 299 (August 1905).
Laestadia Theae.

Horsehair Blight. Tropical Agriculturist, xxv. p. 777 (December 1905).

Mycological Notes. Tropical Agriculturist, xxvi. pp. 68, 69 (Feb. 1906).
Brown Blight ; Branch Canker.

Thread Blight. Tropical Agriculturist, xxvi. pp. 224, 225 (April 1906).

Root diseases of tea. Tropical Agriculturist, xxviii. pp. 292-295 (May 1907).

Miscellanea ; chiefly pathological. Tropical Agriculturist, xxxiii. pp. 521, 522 (December 1909).
Tea root diseases.

A stem disease of tea. Tropical Agriculturist, xlvii. p. 211 (October 1916).
Aglaospora aculeata.

Horsehair Blights. Annals, Royal Botanic Gardens, Peradeniya, vi. pp. 43-68 (August 1915).

Black Rot of tea. Leaflet No. 2 (Feb. 1917), Department of Agriculture, Ceylon. Reprinted in Tropical Agriculturist, xlviii. pp. 156-158 (March 1917).

RACIBORSKI, M. Parasitische Algen und Pilze Javas. Teil 1. Batavia, 1900.

SAWADA, K. Fungus diseases of the tea plant in Formosa. Special Report of the Agricultural Experiment Station, Government of Formosa, No. 11, 1915 (in Japanese).
Pestalozzia Theae Saw. ; *Zukalia Theae* Saw. ; *Scorias capitata* Saw. ; *Neottiospora Theae* Saw. ; etc.

SHAW, F. J. F. The Copper Blight of tea. Agricultural Journal of India, vol. vi. Pt. I. pp. 78, 79 (1911); reprinted in Quarterly Journal of the Indian Tea Association, 1911, Pt. 3, pp. 8, 9.

SPESCHNEW, N. N. v. Die Pilzparasiten des Teestrauches. Berlin, 1907.

SYDOW, H. and P., and BUTLER, E. J. Fungi Indiae Orientalis, Pars III. Annales Mycologici, ix. pp. 372-421 (1911).
Includes *Limacinula Theae* Syd. and Butl.; *Asterina Camelliae* Syd. and Butl.

TANAKA, T. New Japanese fungi. Notes and Translations, iv. Mycologia, x. pp. 86-92 (1918).
Septobasidium Acaciae Saw.; *Helicobasidium Tanakae* Miyabe.

New Japanese fungi. Notes and translations, ix. Mycologia, xii. (1920), pp. 329-342.
Includes *Fusicladium Theae* K. Hara (April 1919); *Mycosphaerella Theae* K. Hara (May 1919); *Mycosphaerella Ikedai* K. Hara (May 1919).

TUNSTALL, A. C. Fungi parasitic on the tea plant in North-East India. Quarterly Journal, Indian Tea Association, 1914, Part II. pp. 52-54.
Nectria cancri.

Copper Blight. Quarterly Journal, Indian Tea Association, 1914, Part III. pp. 96-98.

The fungi parasitic on the tea plant in North-East India, Part VI. Quarterly Journal, Indian Tea Association, 1915, Part III. pp. 53-56.
Fomes lucidus; Grey Blight; Die-back (*Gloeosporium*); Brown Blight; Internal root disease (*Diplodia*).

Tea roots. Part I., Indian Tea Association, Bulletin No. 1, 1916; Part II., Bulletin No. 1, 1918.

Some observations on tea seedlings. Quarterly Journal, Indian Tea Association, 1916, Part III., pp. 103-107.

A stem disease of tea caused by *Nectria cinnabarina* (Tode) Fr. Calcutta, 1918.

An outbreak of Black Rot in Upper Assam. Quarterly Journal, Indian Tea Association, 1918, Part III., pp. 70-72.

Red Rust. Quarterly Journal, Indian Tea Association, 1919, pp. 90-94.

Spraying experiments (against Blister Blight) in Darjeeling. Quarterly Journal, Indian Tea Association, 1919, pp. 145-147.

TUNSTALL, A. C., and BOSE, S. C. Fungus diseases of the tea leaf. Brown Blight, Quarterly Journal, Indian Tea Association, 1920, pp. 37-43. Grey Blight, ibid., 1920, pp. 150-154. Copper Blight, ibid., 1921, pp. 168-171.

WATT, G. The pests and blights of the tea plant. Calcutta, 1898.

WATT, G., and MANN, H. H. The pests and blights of the tea plant. Calcutta, 1903.

WILLIS, J. C. Tea blights. Circulars, Royal Botanic Gardens, Ceylon, vol. i. No. 16 (July 1899).
Grey and Brown Blights.

ZIMMERMANN, A. Über einige an tropischen Kulturpflanzen beobachtete Pilze. Centralblatt f. Bakt., Abt. 2, Bd. vii. (1901), pp. 101-106; 139-147.
Trametes Theae; Corticium javanicum; Protomyces Theae; Necator decretus.

Die Parasiten des Thees. Centralblatt f. Bakt., Abt. 2, Bd. viii. (1902), pp. 50-55.

Untersuchungen über tropische Pflanzenkrankheiten. Erste Mitt. Bericht über Land- und Forstwirtschaft in Deutsch-Ostafrika, Bd. ii. Hft. i. (1904).
Gloeosporium Theae.

INDEX

Acacia arabica, 166
Acacia, leaf disease, 38
Acacia, root disease, 167, 174, 176
Acacia, stem disease, 166
Acervulus, 7
Adhesive mixture, 188
Aecidium, 20
Afzelia palembanica, 165
Agaricaceae, 15
Aglaospora aculeata, 10, 107, 209
Albizzia moluccana, 129, 142, 145, 152, 157, 166, 199
Albizzia stipulata, 159
Aleurodiscus javanicus, 195
Alkaline washes, 189
Alnus nepalensis, 104
Ammonium sulphate, 132
Anker cells, 76
Antheridium, 14
Areca, 166
Armillaria fuscipes, 16, 176, 203
Armillaria mellea, 175, 202, 203
Artocarpus integrifolia, 129, 146, 164
Ascus, 9
Aspergillus, 6
Asterina Camelliae, 42, 207
Azadirachta indica, 161

Bacillus Theae, 64, 194
Bacterial leaf and stem disease, 64
Bamboo, 165, 166, 167
Basidiomycetae, 15
Basidiospore, 15
Basidium, 7, 15
Bela, 161
Berrya Ammonilla, 145, 165
Bird's Eye Spot, 36
"Bitten off" Root disease, 177
Black Rot, 66
Blister Blight, 51, 85
Bois Immortelle, 164
Bombax malabaricum, 161, 165
Bombu, 154, 157
Bordeaux mixture, 185
Botryodiplodia, 9
Botryodiplodia Theobromae, 145, 149, 199, 210
Bracket fungi, 17
Branch Canker, 88
Branch Canker (*Macrophoma*), 96
Branch Canker (*Nectria*), 94
Brown Blight, 31
Brown Root disease, 159
Bukhain, 161
Burgundy mixture, 188
Burrs, 125
Burying prunings, 152

Cacao, 153, 159, 161, 165, 199
Caladium, 179
Callus outgrowths, 126
Camphor, 139
Canker, 88
Capnodium, 41
Caravonica cotton, 159
Carbolineum, 181
Cashew nut, 169
Cassia sp. 161
Cassia javanica, 145
Castanospermum australe, 169
Castilloa, 159, 199
Casuarina, 145, 166
Caustic soda washes, 189
Ceara, 159, 165
Cedrela Toona, 166
Cephaleuros mycoidea, 57, 194
Cephaleuros parasiticus, 56, 64
Cercospora Theae, 36, 211
Cercosporella, 6
Cercosporella Theae, 36, 211
Chaetophoma Penzigi, 48, 210
Chlorosis, 48
Cladosporium, 39
Clamp connections, 2
Coal tar, 181
Coca, 70, 159
Coconut, 145, 153, 165, 166, 167, 199
Coffee, 159
Collar pruning, 117
Collar rot of nursery plants, 119
Colletotrichum, 7
Colletotrichum Camelliae, 31, 191, 192, 211
Colletotrichum Carveri, 191, 211
Conidia, 5
Conidiophore, 5
Copper Blight, 34

Copper in sprayed leaf, 25
Copper-Soda emulsion, 190
Corticium, 19
Corticium (Black Rot), 66
Corticium javanicum, 195
Corticium lilacino-fuscum, 196
Corticium repens, 194
Corticium salmonicolor, 91, 100, 195, 205
Corticium Theae, 73, 205
Corticium Zimmermanni, 196
Croton aromaticus, 157
Cyphella pulchra, 195

Dadap, 117, 129, 139, 153, 159, 164, 199
Dalbergia Sissoo, 166
Darjeeling Stem Blight, 113
Derris, 145
Derris dalbergioides, 165
Desmotascus, 10
Desmotascus neglectus, 100, 207
Didymostilbe, 6
Didymostilbe Coffeae, 106, 212
Dieback (*Gloeosporium*), 33
Dieback (*Nectria cinnabarina*), 103
Dieback (*Stilbella Theae*), 104
Dieback of plucked shoots, 105
Dimidiate, 16
Diplodia, 8, 149
Diplodia vasinfecta, 151, 199
Discomycetae, 12
Discosia Theae, 44, 210
Doona zeylanica, 157
Double leaves, 49
Dwarf leaves, 49

Erythrina, 161
Erythrina indica, 161
Erythrina lithosperma, 139, 159, 164
Erythrina umbrosa, 164
Eucalyptus, leaf disease, 38
Exoascus, 13
Exobasidium, 19
Exobasidium Blight, Japanese, 40
Exobasidium Cinnamomi, 19
Exobasidium reticulatum, 40, 205
Exobasidium vexans, 51, 85, 205
Exobasidium zeylanicum, 19

Facultative parasites, 1
Fasciation, 124
Ficus, 164, 199
Flamboyante, 166
Fomes, 17
Fomes applanatus, 17, 167, 204
Fomes lamaoensis, 17, 159, 200, 204
Fomes lignosus, 17, 162, 201, 204
Fomes lucidus, 165, 202, 204
Fomes semitostus, 162, 201
Funtumia, 159
Fusicladium Theae, 211

Galls, 125
Genera, 5

Gills, 15
Gloeosporium, 7
Gloeosporium dieback, 33
Gloeosporium Theae, 191, 211
Gloeosporium Theae-sinensis, 45, 191, 211
Glomerella cingulata, 192
Gondal fluid, 182
Grevillea, 129, 137, 141, 159, 161, 168
Grey Blight, 27
Grey fungus of dadap, 117, 197
Guazuma tomentosa, 166
Guignardia Camelliae, 34, 192, 207
Guignardia Theae, 10, 192
Gums, leaf disease of, 38

Halmilla, 145, 165
Helicobasidium Tanakae, 116, 206
Helminthosporium, 6
Helminthosporium Theae, 211
Hendersonia theicola, 45, 194, 210
Heteroecism, 21
Hevea, 145, 146, 152, 153, 158, 159, 161, 162, 199
Hexagonia, 18
Hibiscus, 139
Horse-hair Blight, 83
Host, definition of, 1
Hydnum subvinosum, 202
Hymenium, 15
Hymenochaete, 19
Hymenochaete leonina, 201
Hymenochaete noxia, 159, 200
Hypha, 1
Hyphomycetae, 5

Imperfect fungi, 11
Inga Saman, 167
Irpex, 18
Irpex destruens, 111, 196, 205
Irpex subvinosus, 173, 202, 205
Irpex zonatus, 196

Jak, 129, 163, 164
Japanese *Exobasidium* Blight, 40

Keppetiya, 157

Laestadia Camilleae, 192
Laestadia Theae, 192, 207
Leaf disease in nurseries, 44
Leaf diseases, 22
Lichens, 122
Lightning, 128
Limacinula Theae, 42, 206
Lime, as fungicide, 131
Lime-sulphur solution, 188
Limonia alata, 166
Livistonia cochin-chinensis, 165
Lunumidella, 142, 145

Machilus odoratissimus, 161
Macrophoma Theae, 46, 209
Macrophoma theicola, 9, 96, 195, 210

Macrosporium commune, var. *theicolum*, 47
Madar, 161
Mango, 137, 161, 166, 169
Manihot Glaziovii, 165
Marasmius equicrinis, 16, 83, 203
Marasmius pulcher, 78, 194, 203
Marginal corrosion, 32
Massaria theicola, 108, 208
Melanconiaceae, 6
Melia Azedarach, 161
Melia dubia, 142
Meliola, 41
Mesua ferrea, 129, 161
Micron, 2
Moreton Bay Chestnut, 169
Morus indica, 166
Mosses, 122
Moulds, 5
Mulberry, 116, 166
Mycelium, 2
Mycosphaerella Ikedai, 208
Mycosphaerella Theae, 207

Na, 129, 161
Nahor, 161
Necator decretus, 196
Nectria, 10
Nectria cancri, 95, 195, 209
Nectria cinnabarina, 103, 196, 209
Nectria haematococca, 10, 195
Neem, 161
Neottiospora Theae, 210
Nurseries, 121, 177
Nursery root diseases, 176
Nursery root diseases, treatment of, 177

Oidium, 6
Oogonium, 14
Oospore, 14
Oreodoxa, 166
Ostiolum, 8
Oudemansiella apalosarea, 16

Panax, 137, 139
Papaw, 153, 199
Paraphyses, 9
Parasitic, definition of, 1
Penicillium, 6
Perfect fungi, 11
Perithecium, 9
Pestalozzia, 9
Pestalozzia Guepini, 191
Pestalozzia palmarum, 191
Pestalozzia Theae, 27, 106, 191, 211
Phaeosphaerella Theae, 42, 208
Phoma, 8
Phoma Camilleae, 192, 193, 209
Phoma theicola, 42, 193, 209
Phyllosticta, 8
Phyllosticta Theae, 46, 209
Physalospora neglecta, 195
Phytophthora, 13
Piggotia Theae, 210
Pileus, 15
Pink disease, 100
Pithecolobium Saman, 167
Pleospora Theae, 47, 208
Plucking diseased leaves, 23
Poinciana regia, 166
Polymorphism, 11
Polypori, 15
Polyporus interruptus, 17, 169, 204
Polyporus mesotalpae, 17, 169, 204
Polystictus, 17
Pore, 17
Poria, 18
Poria hypobrunnea, 18, 158, 199, 204
Poria hypolateritia, 18, 154, 199, 204
Poria vincta, 199
Protomyces Theae, 197, 206
Prunings, 139, 152
Pruning cuts, treatment of, 180
Puccinia graminis, 21
Pumelo, 145
Pycnidium, 8
Pycnospore, 8
Pyrenomycetae, 9
Pyrularia edulis, 104

Red Root disease, 154
Red Rust, 20, 56
Reproduction of fungi, 4
Resupinate, 17
Rhizoctonia, 118, 178, 197, 202
Rhizomorph, 3
Rim Blight, 39
Ringed shoots, 117
Root diseases, 127
Root diseases of nursery plants, 176
Root-splitting disease, 175
Rosellinia, 10
Rosellinia arcuata, 133, 198, 207
Rosellinia bunodes, 139, 198, 207
Rosellinia mycelium, 2
Rosellinia radiciperda, 198
Rosellinia sp., 141
Rusts, 20

Saprophytic, definition of, 1
Scabbed leaves, 43
Scarlet Mite, 20, 128
Sclerotia, 3
Sclerotium disease, 178
Sclerotium zeylanicum, 178, 212
Scorias capitata, 42, 107
Semecarpus Anacardium, 161
Septobasidium, 114, 196, 197
Septobasidium Acaciae, 116, 205
Septobasidium pedicellatum, 116
Septoria Theae, 46, 210
Septum, 1
Seta, 7
Shishan, 166
Shorea sp., 165
Simul, 161
Sonaru, 161

Sooty Mould, 41
Sorus, 20
Sphaerella Camilleae, 192
Sphaeropsideae, 8
Sphaerostilbe repens, 146, 199, 209
Sporangiophore, 13
Sporangium, 13
Spores, 4
Sporotrichum radicicolum, 200
Spray fluids, 184
Spraying, 25
Spraying machines, 183
Staganospora theicola, 210
Stem diseases, 87
Sterigmata, 15
Stilbella Theae, 104, 196, 212
Stilbum, 6
Stilbum nanum, 195, 196, 212
Stockholm tar, 181
Strobilanthes, 137, 139
Stroma, 7, 8
Stump Rot, 111
Stumps, jungle, etc., 128
Sugar cane, 153, 199
Sum, 161
Symplocos spicata, 154

Tar, coal, 181
Tar, Stockholm, 181
Teleutospore, 20
Tephrosia candida, 139, 158, 174
Thread Blight, 73, 194
Thread Blight, epiphytic, 78
Thread Blight, parasitic, 73
Trametes Theae, 158, 205
Tree Daisy, 179
Trenching, 131
Tumpat Kurundu, 166
Tun, 166

Umphi, 104
Uredinaceae, 20
Uredo, 20
Ustulina vulgaris, 198
Ustulina zonata, 141, 198, 208
Utis, 104

Variegated leaves, 48
Velvet Blight, 114, 196
Venturia Speschnewii, 47, 208

White ants, 92
White Cedar, 166
White Stem Blight, 80
White Toon, 166
Woburn Bordeaux, 186
Woburn Winter Wash, 190

Zoospore, 14
Zukalia nantoensis, 42, 206
Zukalia Theae, 42, 206

THE END

Printed in Great Britain by R. & R. Clark, Limited, *Edinburgh.*